EUR 14260

ANNUAL·REPORT·90

# Institute FOR Remote Sensing Applications

JOINT RESEARCH CENTRE

COMMISSION OF THE EUROPEAN COMMUNITIES

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# 1 EXECUTIVE SUMMARY

## Staff

| | |
|---|---|
| Scientific and Technical Staff | 66 |
| Admin. Support | 4 |
| Secretary Support | 9 |
| Visiting Scientists | 4 |
| Detached Experts | 2 |
| Students | 11 |
| Total | 96 |

## Publications

| | |
|---|---|
| Journal Papers | 19 |
| Conference Papers | 70 |
| JRC Reports | 17 |
| Books/Book Chapters | 15 |
| Total | 121 |

This report presents the achievements of the Institute for Remote Sensing Applications (IRSA) of the Joint Research Centre (JRC) of the Commission of the European Communities (CEC) for 1990. The JRC is a European scientific and technical research centre established by the member states of the CEC. Its four sites in Belgium (Geel), Germany (Karlsruhe), the Netherlands (Petten) and Italy (Ispra) house 9 Institutes, each with its own focus of expertise.

IRSA, based at Ispra, was created in November 1988 as the result of a decision taken by the Council of Ministers regarding the restructuring of the Joint Research Centre. At this time the Institute was set a number of objectives:

- to evaluate and demonstrate possible applications of remote sensing in support of the sectorial policies of the Commission of the European Communities in areas such as:
  - Common Agricultural Policy (CAP) (agricultural statistics, land use),
  - Environmental Policy (land and sea protection),
  - Development (food resources and environmental protection in developing countries),
  - Fisheries (resources evaluation and conservation),
  - Regional Aid.
- to undertake research on advanced methods for the interpretation and utilisation of satellite data including their integration with geographical data.
- to help to stimulate the scientific community in the use of European satellites such as ERS-1, SPOT and the Polar Orbiting Platforms; this objective is complementary to that of the European Space Agency (ESA).

The scientific, regulatory and administrative bodies of the Commission are IRSA's main users. This takes a number of forms, the main one of which is the Specific Programme which incorporates a body of research which is defined and approved by the CEC Member States via the JRC's Governing Board.

The second, and increasingly more important form, is the work that IRSA undertakes as Scientific and Technical Support to the Sectorial Policies of the Commission. As such IRSA undertakes research on behalf of Directorates General (DG) of the Commission, the objectives of the research being given by the DG. Currently IRSA undertakes such work for DG I (External Relations), DG VI (Agriculture), DG VIII (Development Aid) and DG XI (Environment).

The third element of IRSA's programme is entitled Exploratory Research. This is a percentage of the Specific Programme that allows IRSA scientists to test new ideas that are not currently contained within the Specific Programme, but that show promise for future applications. This research is selected by the JRC's Governing Board on the basis of proposals made by JRC scientists.

In addition IRSA's programme provides the opportunity for national government and private coorporations to utilise IRSA's resources to carry out contract research. With facilities and expertise unique in Europe, IRSA serves a special role as a resource for organisations whose research needs exceed their own internal capacity. or who wish to benefit from the availablity of specific IRSA facilities or expertise.

# 1.1 INSTITUTE STRUCTURE

The Institute currently incorporates 79 permanent with an additional number of doctorate and post-doctorate students, visiting scientists and detached national experts. These staff are divided into five Units:

## Agriculture Information Systems

The implementation of the CAP is one of the most important objectives of the CEC. In order to discharge its duties the Commission requires an effective system of monitoring and control. At present it uses statistics produced mainly to fulfill national requirements. Unfortunately these statistics are not always directly comparable, making it difficult to compile an homogeneous statistical data set for the entire CEC.

A decision by the Council of Ministers in September 1988 approved a Pilot Project to demonstrate the application of remote sensing to the generation of agricultural statisitics for the CEC. IRSA has been charged with the project, the orientation of which is defined by the priorities of both Directorate General VI (Agriculture) and the Statistical Office of the European Community (Eurostat).

## Environmental Mapping and Modelling

This Unit has been conceived as a contribution to the implementation of the CAP in the form of the management of marginal agricultural regions, and of the environmental policy. In particular the Unit's objective is to provide up to date information on the state of the environment which can be input into CEC data bases such as CORINE.

As a complement to these activities a Collaborative Programme has been developed consisting of a series of joint projects executed by a network of some 35 national institutes and laboratories in Europe. The main trend of these studies is towards the application

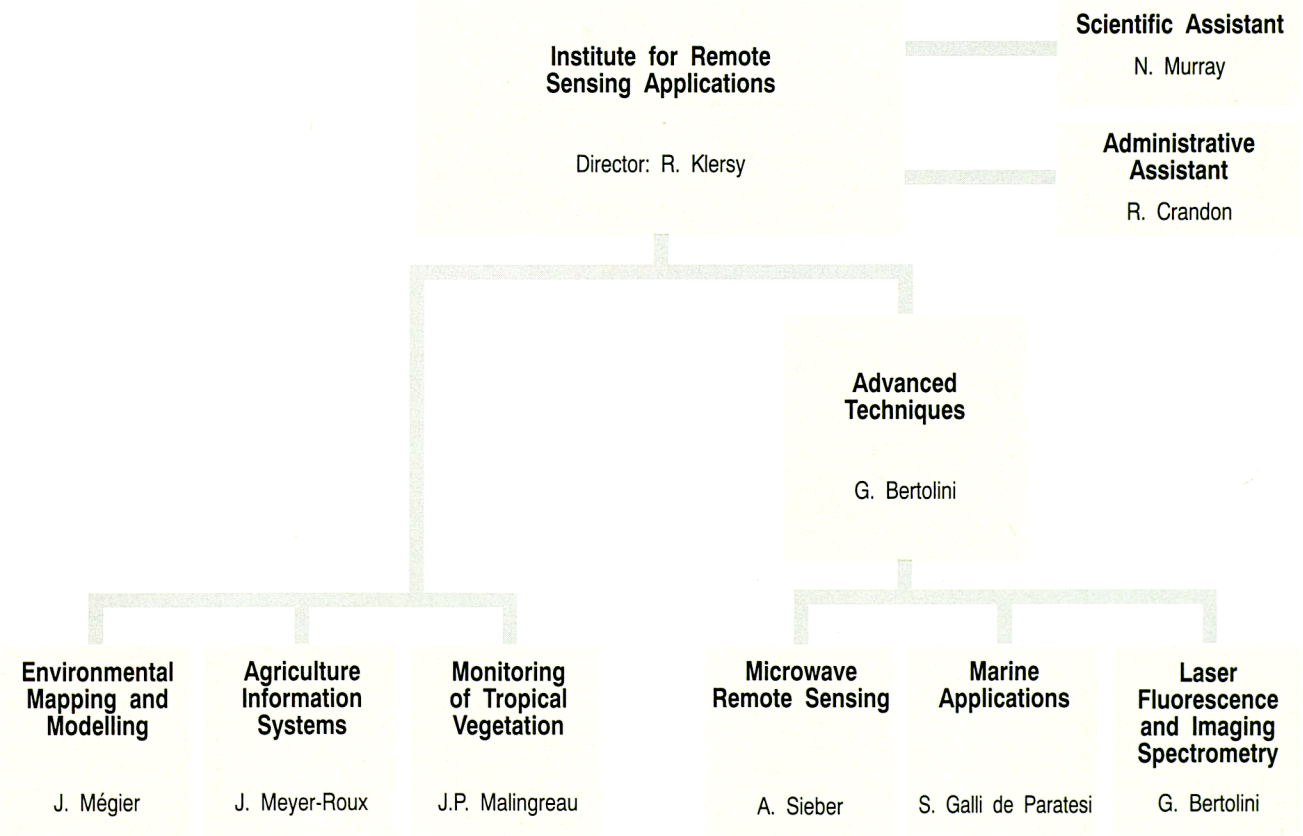


*Fig. 1.1: Institute organigramme.*

of earth observation data for the management and monitoring of land use, agriculture, forestry, pasture and natural vegetation in typical test sites in European marginal areas.

### Marine Environment

The scope of this Unit is to demonstrate and validate methodologies for the practical use of data from space and airborne sensors in both operational applications and scientific investigations related to the marine environment. In order to undertake this overall objective three activities have been defined:

- Ocean Colour European Archive (OCEAN).
- Coastal Upwelling Off the Coast of West Africa
- Global Change - Marine Biosphere Atmosphere Interaction

### Monitoring Tropical Vegetation

In order to respond to the needs of development policy within the CEC (Directorate General VIII) IRSA is using earth observation in three application areas:

- Agricultural Production: These studies are undertaken in cooperation with the project "Monitoring Of Renewable Resources In The Sahelian Countries", which is supported by the Comité Permanent Inter-Etats de la Lutte contre la Secheresse au Sahel (CILSS) and the European Development Fund (EDF).
- Hydro-Ecological Studies: Stratification of the upper Niger basin in Guinea is being undertaken using conventional morphometric measurements and satellite derived observations using Landsat Multi-Spectral Scanner (MSS) imagery. SPOT HRV imagery is being used to assess seasonal variations insurface water area. AVHRR data are used to provide inter-annual comparisons of vegetation dynamics.
- Tropical Deforestation: This is one of the most pressing environmental problems of the 20th century. AVHRR time series at both 1km and 4km spatial resolution are being used in the framework of a global tropical deforestation assessment.

### Advanced Techniques

Besides the development of applications of proven space borne sensors in the visible and infra-red range there is a need for the evaluation and promotion of more advanced remote sensing techniques, involving basic, systematic and long-term research. In order to address this requirement an Advanced Techniques Unit has been established within the Institute that is involved in the following activities:

- Microwave Remote Sensing.
- Imaging Spectrometry.
- Time Resoved Laser Fluorosensor.

# 1.2 REPORT STRUCTURE

The report is divided into Chapters, with a Chapter dedicated to each of the Institute's Units.

Each Chapter follows the same format with an Introductory section defining the overall objectives of the Unit, its resources and the number of publications it has produced in 1990.

This is followed by sections on each of the activities of the Unit. These also follow a common form with a description of the objectives of the activities, a series of milestones for 1990 and a description of the work undertaken in 1990.

# 2 AGRICULTURAL INFORMATION SYSTEM

*Contact:* J. Meyer-Roux

## Staff

| | |
|---|---|
| Scientific and Technical Staff | 10 |
| Secretarial Support | 1 |
| Students | 2 |
| Visiting Scientists | 0 |
| Detached Experts | 2 |
| Total | 15 |

## Publications

| | |
|---|---|
| Journal Papers | 5 |
| Conference Papers | 10 |
| JRC Reports | 1 |
| Books/Chapters | 3 |
| Total | 19 |

## Facilities

- Micro Vax 3900 with MARS-PED software to process data for agricultural statistics, and ERDAS image processing software
- Matra/SUN 3 to develop AVHRR pre-processing software
- SUN 4 with ARC/INFO

The implementation of the Common Agricultural Policy (CAP) is one of the most important objectives of the CEC. In order to discharge its duties the Commission requires an effective system of monitoring and control. At present it uses statistics produced mainly to fulfill national requirements. Unfortunately these statististics are not always directly comparable, making it difficult to compile an homogeneous statistical data set for the entire CEC.

A decision by the Council of Ministers in September 1988 approved a Pilot Project to demonstrate the application of remote sensing to the generation of agricultural statisitics for the CEC. IRSA has been charged with the project, the orientation of which is defined by the priorities of both Directorate General VI (Agriculture) and the Statistical Office of the European Community (Eurostat). Based upon their requirements the priorities of the project are as follows:

- to distinguish, identify and measure the surface area of important crops;
- to assess production early enough for strategic policy decisions;
- to forecast agricultural production.

These priorities have been broken down into seven Actions:

**Action 1:** Regional inventories of crop acreages using a combination of high spatial resolution satellite data and ground work.

**Action 2:** Near real time monitoring of vegetation condition on a continental scale using low spatial resolution data from meteorological satellites.

**Action 3:** Agro-meteorological modelling of plant processes to forecast yield on a regional scale.

**Action 4:** Rapid estimates of change in acreages and potential yield using image interpretation of high spatial resolution satellite images of sample sites.

**Action 5:** Advanced agriculture information system integrating the products of all the other Actions.

**Action 6:** Systematic ground data collection for the purposes of classification and interpretation of satellite data.

**Action 7:** Long term research into new systems (e.g. microwave) or software (e.g. parallel processors) and the use of geographical information systems (GIS) for agricultural monitoring.

The results of the project will form part of an "Advanced Information System for Agriculture". This system will be based on information from remotely sensed data derived from high and low spatial resolution satellite sensors, and on sophisticated methods of data interpretation, including agro-meteorological models.

# 2.1 PILOT PROJECT FOR THE APPLICATION OF REMOTE SENSING TO AGRICULTURAL STATISTICS (in support of DG VI Agriculture and EUROSTAT)

***Summary of objectives***

*The Directorate General VI (Agriculture) of the Commission of the CEC and the Statistical Office of the European Communities wish to examine the degree to which satellite-based information can complement conventional agricultural statistics for the land area of the 12 Member Nations. The project is designed to develop techniques to demonstrate the use of remote sensing and agro-meteorological modelling for agricultural inventory and monitoring. In order to achieve this objective, the work has been broken down into seven main Actions.*

## 1990 Programme of Work

### Introduction

The programme of work of the Pilot Project remains unchanged: to demonstrate operational systems, and, in some cases, to hand over to regional or national organisations once the system is truly tested. The work of the Pilot Project is mainly carried out by contracts with regional or national organisations, private companies and universities. The staff of the project are responsible for guiding and monitoring these contracts.

### Action 1

The objective of Action 1 is to estimate the area under various crops at regional scale. The area in which the inventory is to be carried out is imaged using high spatial resolution sensors (either the 30-metre Thematic Mapper or the 20-metre SPOT instruments). At the same time, ground teams go into the field to list the crops present in all the fields located in a large number of sample squares. These squares, called segments, are 700 metres across, and are located using a scheme which takes into account strata constructed from agriculturally important considerations.

The ground data are used to help to classify the respective images, and the percentages of crops in the area are estimated directly. This technique has the advantage that its precision is accurately known, and that it is an objective technique which is standardised for all the countries in which the inventory is carried out. Action 1 has successfully shown that the technique of using a combination of high spatial resolution satellite and ground data works for a wide range of crops. The increase in precision for a given cost has encouraged several organisations to take over major parts of the activity.

### 1990 Milestones

- Many small ITTs were issued
- A major ITT issued in August listed 22 operations from all 7 Actions. The value of the contracts issuing from this ITT amounted to more than a million ECU.
- Action 1 was extended thanks to the contribution and collaboration of several Agricultural Ministries and regional statistical offices:
  - In France, new regions were added to extend the survey to cover the whole of the Region Centre and Ile de France.
  - In Spain, the provinces of Burgos and Palencia have been included.
  - In Greece a three-year plan was established to cover the whole of the country.
  - In Portugal, an agreement was reached to cover the southern regions starting next year.
  - In Italy, collaboration with the Emilia-Romagna Region is intended to determine the precision with which the area frame technique can estimate the value of variables which are not measured as areas.
- The Geographic Information System ARC/INFO was installed.
- AGROMET, REGIO and CRONOS data sets and the digital soils map of the EC were acquired.
- In Action 4, 20 active sites were analysed, 6 agricultural status bulletins were produced, and all fifty sites were inventoried by ground teams.
- A collaborative support group (the Expert group on Agriculture in Mediterranean Regions) was set up to study the problems specific to monitoring agriculture in the Mediterranean regions with remote sensing.
- Two Action 3 support groups were set up: SuGrAM (SUport GRoup for Agricultural Meteorology) and Sols et GIS (soils and geographic information systems).
- Software (TTS) was written to compare ground data collected in the segments with satellite data for the same site and to convert the information rapidly into statistics.

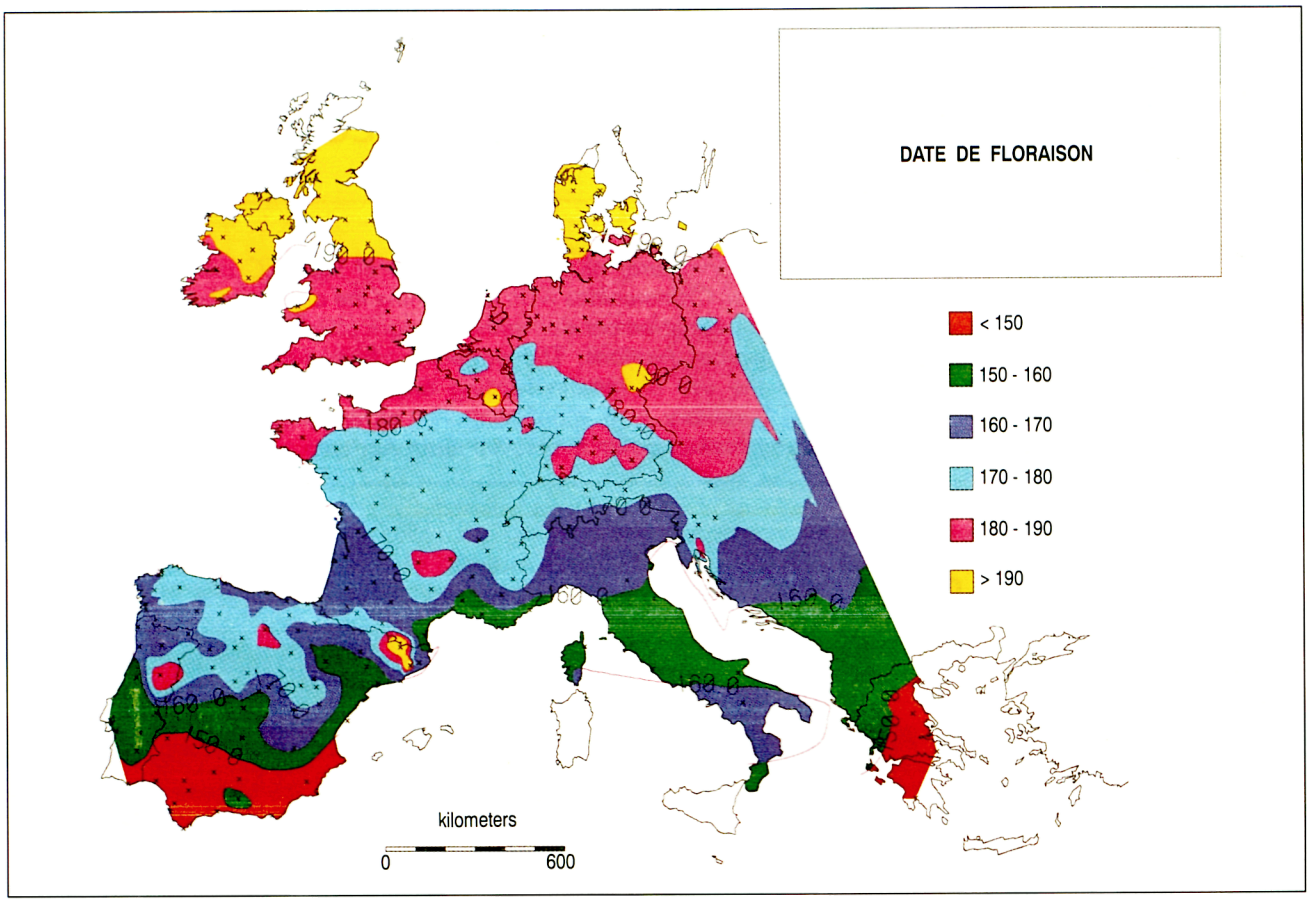


*Fig. 2.1: Mean flowering date of wine grape as computed from agrometeorological models, with the support of vineyard research institutes from the member states.*

## Action 2

The objective of Action 2 is to provide up-to-date information on the state of the vegetation over the whole of Europe. The data are derived from meteorological satellites, specifically the AVHRR instrument on the NOAA series of satellites. These data are collected at low spatial resolution (one kilometre at nadir), and can be used as an indicator of crop condition - for example, to monitor drought or frost.

The project directed ten contracts, including two contracts designed to monitor near-real-time vegetation condition, as precursors of the project's own system. A third contract demonstrated that under certain conditions these meteorological data can be used to indicate the yield of major crop types.

In preparation for next year's work, Action 2 arranged with the European Space Agency that data will transit through Ispra en route from a selected ground station to the ESRIN establishment at Frascati. This ensures a continual supply of timely data.

## Action 3

The objective of Action 3 is to model plant processes and to forecast yield on a regional scale on the basis of climatic data. The main activities centred on monitoring the work done in 13 contracts. These contracts have had six main themes:

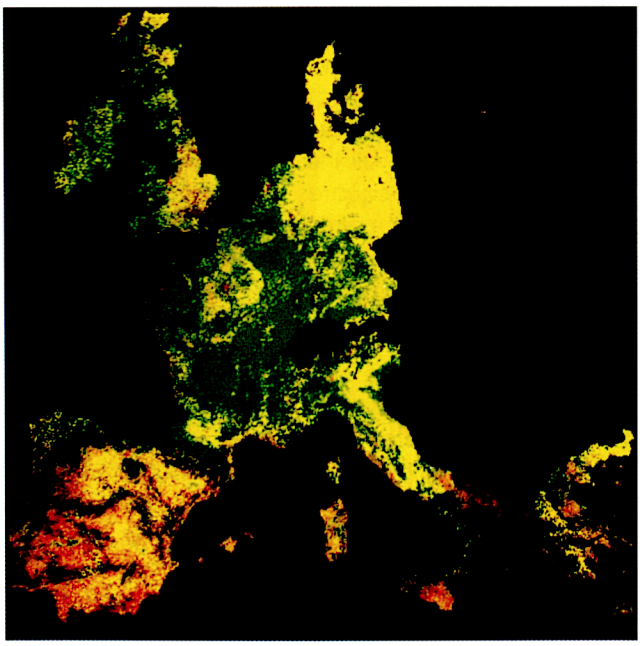

*Fig. 2.2: European mosaic of NOAA/AVHRR images indicating vegetation performance, produced daily by the SPACE software.*

- to inventory the agro-meteorological knowledge of the main crops of the Community;
- to develop a method for estimating potential evapo-transpiration over the whole of Europe;
- to update and correct the 1:1000000 scale digital soil map of the EC;
- to model the quality of the growing season of a region, irrespective of the crops growing in that region;
- to integrate fruit and wine production in the OSCE model;
- to estimate grape production using pollen capture.

### Action 4

The objective of Action 4 is to provide early estimates of change from year to year in acreages and potential yield. The information derives from repeated acquisitions of high spatial resolution satellite images of sample sites. The contractor has a team of interpreters which examines each new image as it arrives to identify as accurately as possible each crop. Early images tend to contain more general information (spring or winter crops, for example), and the information gets more precise as the year goes on. Agricultural status bulletins are published 6 times in the year.

### Perspectives for 1991

Action 1: Action 1 will continue in the same orientation and with the same objectives. However, the proportion of work carried out under direct contract to the Pilot Project is expected to diminish rapidly over the next few years. The contribution of the project will be increasingly in scientific and technical support.

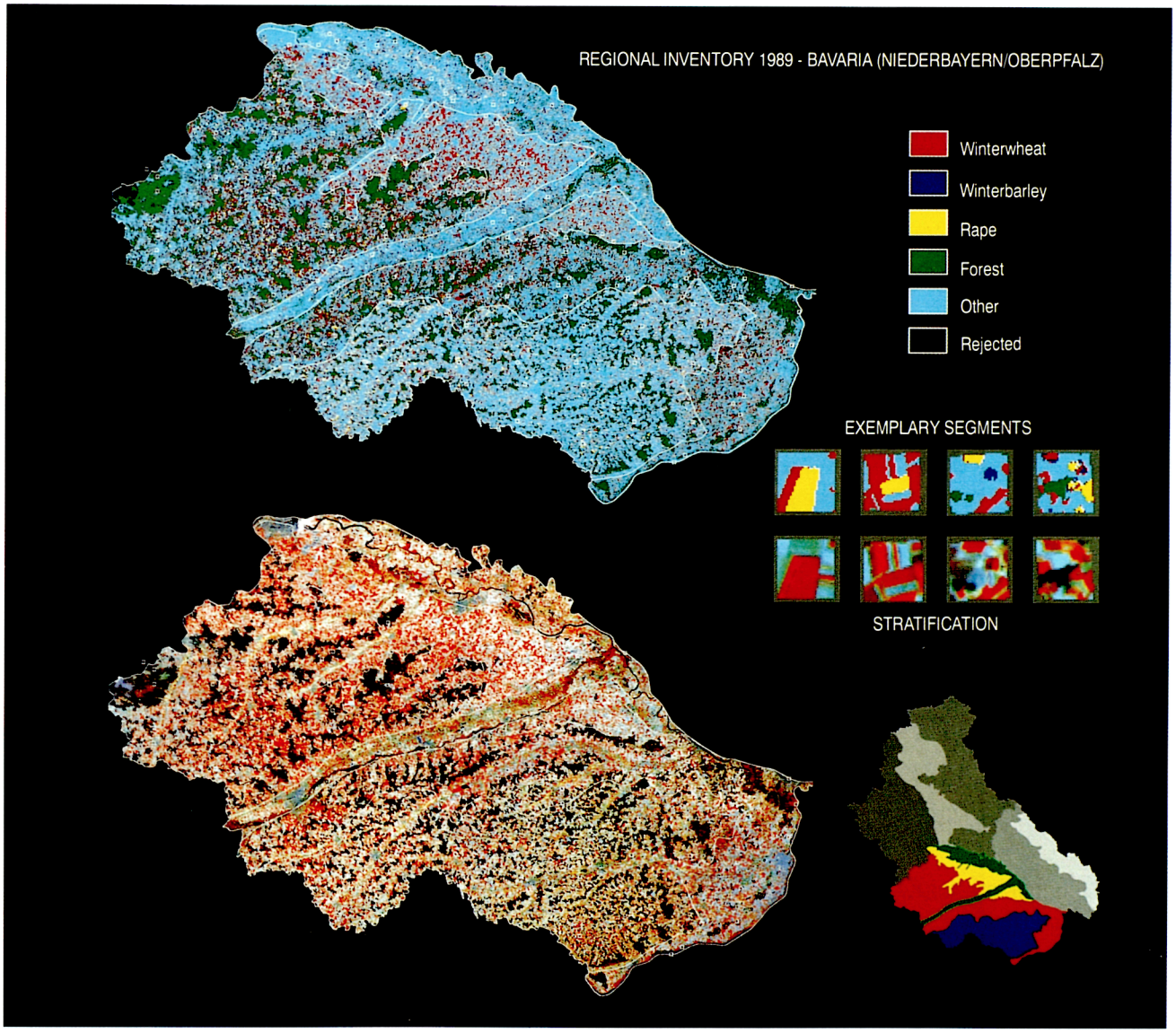


*Fig. 2.3: One of the five regions (Bayern Munich) covered by the Action 1 regional inventories study showing image (Landsat TM) and classification results for the area near Niederbayern.*

**Action 2:** In 1991 Action 2 will take delivery of the specially-designed Software to pre-Process AVHRR data for the Communities of Europe (SPACE). Acceptance of this package will mark the start of data processing within the project to produce an AVHRR-based agricultural status bulletin for DG VI.

**Action 3:** The project will take delivery of the software to model the quality of the growing season. It will establish the final links with the meteorological network, gaining access not only to long-term historical data but also to real-time information.

**Action 4:** The operation will extend to 30 sample sites. The Pilot project will supply DG VI and the OSCE with facsimile agricultural status bulletins every two weeks. An additional 3 sites will be located in eastern Germany.

The plan for the Pilot Project covers a period of ten years; the current Council Decision approves its execution until the end of 1993, a review, leading to a follow-up decision taking place in 1991. The total financial envelope for 1989 to 1993 is set at 35.5 Mio ECUs and a substantial fraction of this sum will be allocated by the Joint Research Centre (which has overall responsibility for the project), to private and public contractors in the Member States.

PARLEMENT EUROPÉEN
BIBLIOTHÈQUE

# 3 ENVIRONMENTAL MAPPING AND MODELLING

*Contact:* J. Mégier

## Staff

| | |
|---|---|
| Scientific and Technical Staff | 16 |
| Secretarial Support | 1 |
| Students | 4 |
| Visiting Scientists | 0 |
| Detached Experts | 0 |
| Total | 21 |

## Publications

| | |
|---|---|
| Journal Papers | 3 |
| Conference Papers | 7 |
| JRC Reports | 6 |
| Books/Chapters | 2 |
| Total | 18 |

## Facilities

- Vax 4000 with Microvax 3800 in cluster with ERDAS image processing software
- VIZIR colour laser high precision film recorder
- Manual and automatic (video-camera) digitizing facilities
- Colour paper printers
- Vax stations 3100 with artificial intelligence software and Arc/Info
- Microvax 2000 with Oracle relational data base
- SUN 4 for neural network software
- PC's for ERDAS and Arc/Info
- In-house image processing and analysis software

This Unit has been conceived as a contribution to the implementation of the Common Agricultural Policy (CAP) in the form of the management of marginal agricultural regions, and of the enviromental policy, in particular to provide up to date information on the state of the environment which can be input into CEC data bases such as CORINE.

The major objectives of the research are as follows:

- the development of methods integrating satellite earth observation data with conventional data in order to provide accurate and updated information on land occupation in the "less favoured areas" of the CEC member states;
- the development of models using this information to descibe and characterise these areas and their spatio-temporal evolution as an aid to decision making and management.

In so doing special emphasis is given to the development of new techniques for the interpretation of earth observation data. In particular this involves the application of geographical information systems (GIS), expert systems and neural network techniques to enhance information extraction.

As a complement to these activities a Collaborative Programme has been developed consisting of a series of joint projects executed by a network of some 35 national institutes and laboratories in Europe. The main trend of these studies is towards the application of earth observation data for the management and monitoring of land use, agriculture, forestry, pasture and natural vegetation in typical test sites in European marginal areas, and for the monitoring of land degradation and soil erosion processes.

# 3.1 LAND USE PLANNING IN EUROPEAN MARGINAL AREAS

***Summary of objectives***

- *Development of methods for integrating satellite Earth observation data with conventional data in order to provide accurate and updated information on land occupation in the "less favoured areas" of the CEC member states.*
- *Development of models using this information to describe and charaterize these areas and their spatio - temporal evolution as an aid to decision making and management.*

## 1990 Programme of Work

### Introduction

During 1990 the activity has concentrated on four main aspects:

- Land use mapping and land cover statistics over the Ardèche test area;
- High resolution imaging spectrometry for soil erosion risk assessment;
- Advanced techniques for image understanding;
- Collaborative Programme

The work undertaken in each of these is summarized below.

### Land Use Mapping and Land Cover Statistics Over the Ardèche Test Area

Previous experience of data analysis in the mediterranean marginal (or less favoured) area in the Ardèche Department (F) demonstrated that for obtaining accurate enough statistics and mapping accuracy (at least an average of 80%) in such a difficult area, multitemporal analysis throughout the vegetative cycle is mandatory. This has led to an effort to solve two challenging preprocessing problems in the preceding years of work:

- superposition of the time series of images with sub-pixel accuracy and registration with topographical maps;
- correction of the data for the varying atmospheric effect in order to derive meaningful time varying features for characterizing the various vegetation categories.

Using this approach a mapping accuracy of around 80% was obtained by the multitemporal processing of a reduced part of the Ardèche. The multitemporal processing of the whole area (5.600 $km^2$) using four dates of TM data is underway and the final result is expected at the end of 1991.

### 1990 Milestones

| | |
|---|---|
| April | First version of the rule-based segmentation algorithm working |
| May | Evaluation of the first phase of the Collaborative Programme was completed |
| June | Atmospheric correction and radiometric calibration models ready and applied to GERIS imaging spectrometer data |
| October | Geometric registration of GERIS data (including relief effect correction) and completion of Arc/Info data base including geology, pedology and vegetation layers |
| December | First successful comparison of results between GERIS airborne data and field and laboratory spectral measurements |

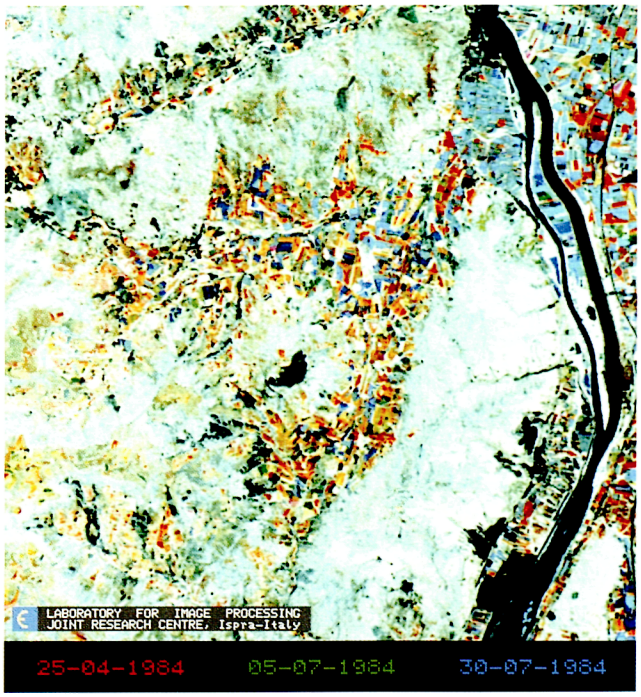


*Fig. 3.1: The Ardèche: multi-temporal NDVI atmospheric correction, geo coded, chomerac area.*

## High Resolution Imaging Spectrometry for Soil Erosion Risk Assessment

The analysis of the data collected in the southern part of the Ardèche Department from the European Imaging Spectrometry Aircraft Campaign (EISAC) that took place in 1989 incorporated two tasks in 1990:

- Data pre-processing and quality analysis
- Preliminary thematic analysis and signature extraction

*Data Pre-Processing and Quality Analysis*

An adequate analysis of these data requires a thorough evaluation of both wavelength and radiometric calibration, and a conversion of the data to reflectance factors so that individual spectra can be compared directly with laboratory data or spectral field measurements. In order to achieve this the following preprocessing and analysis have been undertaken on the data:

- Atmospheric correction;
- Spectral band position assessment;
- Spectral bandwidth evaluation and radiometric calibration;
- Instrumental noise evaluation.

*Preliminary thematic analysis and signature extraction*

First results of the analysis of the data were obtained which gave a very good correspondance between GERIS data in the range 2 - 2.5 μm and field and laboratory measurements in the detection of absorption features of soils and rocks constituents, in particular ALOH and $CO^3$ and their various mixtures. This capability is considered important for assessing vegetation-soil mixtures and analysing exposed soils in land degradation and soil erosion studies.

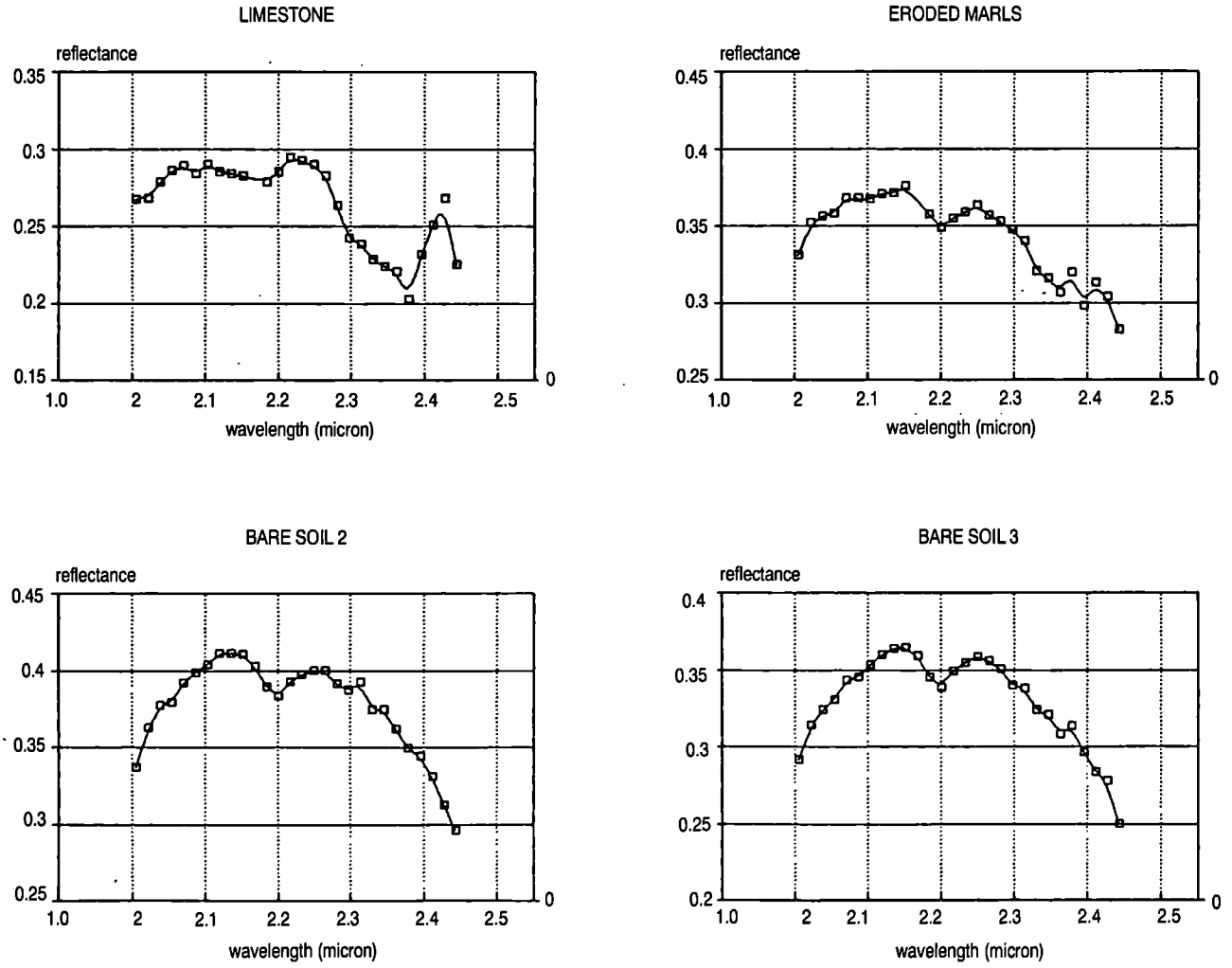


*Fig. 3.2: Derived from GERIS data of the Ardèche during the EISAC campaign. Short-wave infrared peflectance signatures from typical ground targets in the study site.*

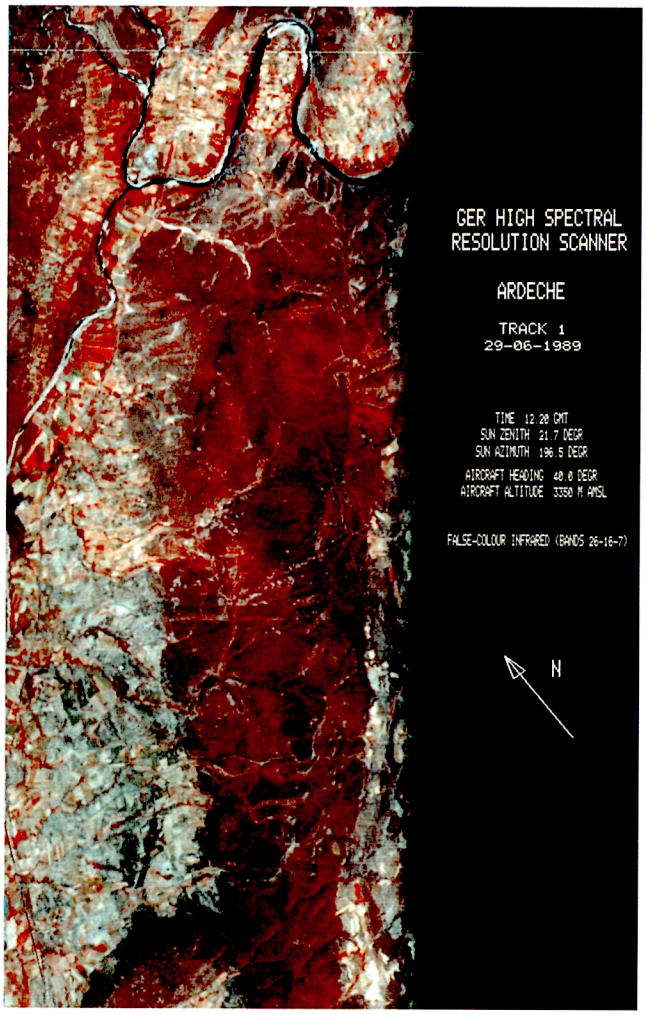


*Fig. 3.3:GERIS High Spectral Resolution Scanner. Image of the Ardèche region in France acquired during the EISAC Campaign.*

## Advanced Image Processing Development

Three techniques of advanced image processing have been evaluated in 1990:

- Automatic rule-based image segmentation;
- Expert systems for land cover discrimination and mapping;
- Neural network techniques for image classification.

The last two techniques are discussed in more detail in a later Section of the Report. The work undertaken on automatic image segmentation is summarized below.

A new technique has been developed to segment multispectral remotely-sensed images to enable Landsat Thematic Mapper (TM) imagery to be more effectively used in land cover mapping and inventories. The purpose is to produce maximal homogeneous regions in an image which represent the true spatial extent of ground features such as fields and which takes into account image noise and spectrally impure pixels in the border zone near physical segment boundaries.

The procedure is also aimed at minimizing the existence of segment holes and at producing relatively smooth segment outlines. This technique combines an optimal best-merge region growing approach and spectral-spatial clustering with rules for allocating spectrally uncertain pixels to segments on the basis of support from their spatial context.

The algorithm has been employed to segment TM imagery over Greece and the results show that the procedure performs well giving an accurate segmentation which is usable in thematic applications.

## Collaborative Programme

The programme was initiated in 1985 with the aim of promoting the use of remote sensing for land use planning in the less favoured marginal areas of the Community; approximately 25 European institutions have been involved. The first phase of the programme ended in 1989.

1990 was devoted to the analysis of the results and to plan the continuation of the activities, which will be much more oriented towards environmental protection in the future.

The main results obtained up till now concern soil moisture modelling, forestry and grassland monitoring and land use planning in uplands and in mediterranean regions.

A PC-based inexpensive package for image processing and GIS training has also been developed and distributed among the associated laboratories.

For the second phase, the programme has been reorganized around five main themes for which nine research contracts have been defined: agriculture, forestry, grassland and natural vegetation, environmental protection and GIS and training.

## Perspectives for 1991

- The land use mapping over the Ardèche Department by multitemporal analysis of TM data will be completed
- Research on the semi-automatic updating of the CORINE land cover data base will be initiated
- The analysis of imaging spectrometry data will continue with GERIS and AVIRIS data acquired in 1991 (NASA AVIRIS and EARSEC campaigns)
- The development of automatic image segmentation, expert systems and neural network for image classification will proceed
- The Collaborative Programme will be developed along the main themes mentioned above.

# 3.2 THE EUROPEAN IMAGING SPECTROMETRY AIRBORNE CAMPAIGN (EISAC)

***Summary of objectives***

- *Development of imaging spectrometry for the puposes of agriculture, forestry, soil science and marine biology*
- *Familiarisation of a broad community of European users with imaging spectrometer data*
- *Definition of geophysical parameters to be derived by future spaceborne missions*
- *Data analysis for applications in agriculture, forestry, soil science and oceanography*

## 1990 Programme of Work

### Introduction

In the framework of the joint ESA/JRC EISAC campaign imaging spectrometer flights over seven European test sites were successfully performed using Moniteq's Fluorescence Line Imager (FLI/PMI) and the 63 band multispectral scanner of Geophysical Environmental Research Corporation (GER) between May 15th and the end of June 1989. This campaign permitted important expertise in the field of radiometric and atmospheric correction and processing of imaging spectrometer data, obtained under European conditions, to be gained.

After the acquisition and preprocessing of airborne and ground data in 1989, the 1990 EISAC activities mainly concentrated on data distribution and data evaluation.

The EISAC data evaluation programme, which was coordinated by IRSA, comprises a wide range of applications in agriculture, forestry, geology/soil science and oceanography/marine biology. In the first phase data evaluation was focussed on quality assessment, and the radiometric and atmospheric correction of the airborne data.

In the second phase thematic data evaluation and spectral signature modelling was undertaken with the objective being to optimize approaches for the exploitation of the data of future spaceborne imaging spectrometers with moderate (MERIS, MODIS) and high spatial resolutions (HIRIS, HRIS), and to also prepare for future airborne spectrometer campaigns, such as EARSEC and MAC-EUROPE, both of which will take place in 1991.

### Data Distribution

For each test site a data package including airborne and ground data has been prepared and distributed to 30 European experimenters selected on the basis of a "Call for Experiments".

**1990 Milestones**

| | |
|---|---|
| March | All test site ground data packages prepared by experimenters received at IRSA |
| July | All test site ground data checked at IRSA and distributed (50 data sets) to selected experimenters |
| July | All the data acquired during the EISAC Campaign (GER and FLI/PMI) distributed by ESA-ESRIN Frascati (286 CCT's) to EISAC experimenters |
| July | EISAC meeting of the experimenters to discuss the data evaluation work. |

### Quality Assessment of the Data

The first phase of the evaluation programme was dedicated to the assessment of the quality of airborne FLI/PMI and GER data. The data have been investigated independently by IRSA and the campaign Coordinating Investigators (CI), aiming mainly at the validation of the noise level, effective spectral resolution and radiometric calibration.

*GER data*

The signal/Noise Ratio (SNR) for the VIS/NIR module of the GER of 5-10 for low reflectance targets and 20-50 for high reflectance targets has been calculated.

For the SWIR II module the best SNR was found in bands 40-50 where the SNR is 25-40, whereas SNRs decrease to approximately 5-10 in bands 36-38 and 55-63.

A comparison of Lowtran standard atmosphere absorption bands with GER spectra at band positions potentially sensitive to gaseous absorptions led to the conclusion that the nominal bandwidth of 12.3 nm in the VIS/NIR was not kept. An effective bandwidth

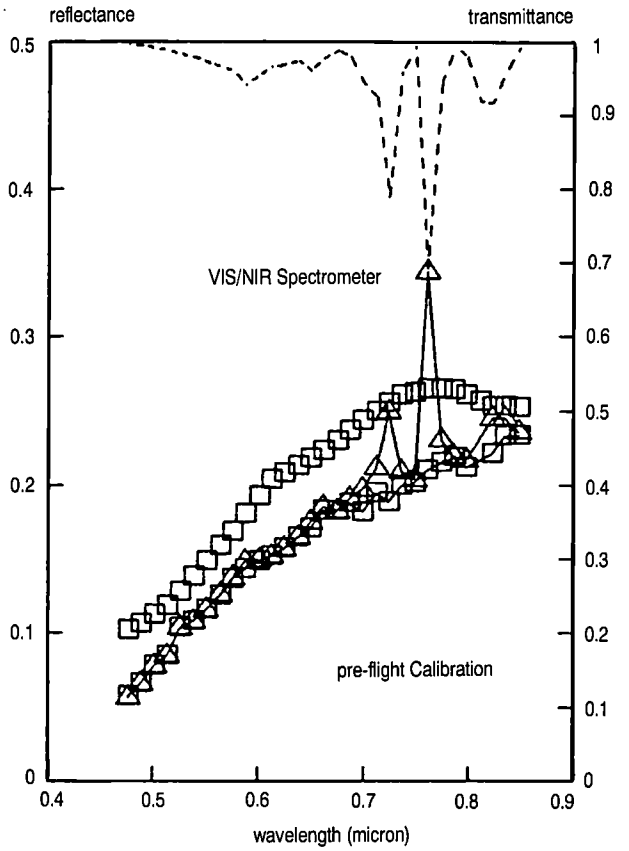


*Fig. 3.4: GER Freiburg, 13 June 1989: measured and modeled reflectance of the calibration target (sandy soccer field, Rothaus, FRG), pre-flight calibration.*

of 50 nm has been estimated indicating that the VIS/NIR spectrometer was defocussed. The given bandwidth of the SWIR II module (2000-2500 nm) was slightly exceeded.

The observation of considerable differences between GER spectra with applied preflight radiance factors and field spectra measured during the overflights required increased efforts to achieve reliable calibration factors on the basis of in-flight data. The investigations led to new tables of radiance factors and offsets for all channels obtained by fitting the GER radiances to measurements and radiative transfer calculations.

*FLI/PMI data*

SNRs over dark targets have been estimated to be in the range of 20 to 30.

The geometric characteristics of the roll corrected data were considered to be sufficient, whereas the radiometric quality suffered from the moderate SNR and deficiences in inter-camera calibration, detector normalisation and geometric characteristics.

*Table 3.1: The band specifications of the GER imaging spectrometer.*

| Wavelength Range | Module | Number of Channels | Sampling Interval |
|---|---|---|---|
| 0.477-0.843 μm | VIS/NIR | 31 | 12.3 nm |
| 1.44-1.80 μm | SWIR I | 4 | 120 nm |
| 2.005-2.443 μm | SWIR II | 28 | 16.2 nm |

## Thematic Data Evaluation

Upon the basis of the verified data quality and reliable in-flight calibration the second phase of the EISAC programme, dedicated to thematic data evaluation, was started.

First attempts concentrated on the mapping of chlorophyll distribution and pollution in coastal waters and on the spectral differentiation of various land surfaces and ground covers.

Following this encouraging results could be achieved in the discrimination of different soils and rocks by using their characteristic spectral features in the short wave infrared (SWIR) of GER data between 2.0 and 2.5 μm. over the Ardeche test site

In the Somerset test site variations between different applications of nitrogen fertilizer could be detected with evidence of a blue shift and in terms of the levels of green, red and NIR reflectance.

With respect to the development of the Medium Resolution Imaging Spectrometer (MERIS), to be launched in the framework of the first ESA Polar Platform Mission, EISAC data will be used to investigate the:

- quantification of the nature and physical status of vegetation communities
- limits for the detection of plant spectral features in mixed soil-plant spectra
- influence of different soil properties on the mixture of spectra.

To this end two on going study-contracts with external institutes, the British National Space Centre (BNSC-NERC, UK) and the Institute of Physical Geography, University Freiburg (D), have been placed. Supplementary Compact Airborne Spectral Imager (CASI) data, covering the spectral range from 0.4 m to 0.9 μm, will be included into this part of the research programme, the data were acquired over the Freiburg test site on July 20th of behalf of IRSA.

## Perspectives for 1991

Two important meetings are foreseen:

January EISAC progress meeting on data evaluation
April Final EISAC workshop.

The EISAC Campaign will officially close in 1991.

# 3.3 EXPERT SYSTEM FOR LAND COVER DISCRIMINATION AND MAPPING

***Summary of objectives***

- *To improve the performances of conventional classification methods by making use of ancillary geographic information and additional relevant human common-sense knowledge in processing satellite imagery.*
- *To encode all this background and ancillary information in an expert system able to properly combine it with the spectral information coming from satellite data.*

## 1990 Programme of Work

### Introduction

The purpose of this exploratory research is to permit the production of map -like products from satellite images by making more use of ancillary geographic information and also additional relevant human common-sense knowledge in processing satellite imagery. Background knowledge encoded in an expert system can be used as an aid both in refining pixel or segment classifications by helping to overcome some of the errors encountered in applying a strictly numerical or statistical analysis to pixel radiances, and also in spatially simplifying the array of satellite image information to make it conform more closely to the expectations of a cartographer.

Three different kinds of expert system rules in remotely-sensed image analysis are used:

- Geographic context rules to help refine pixel/segment classifications on the basis of background geographic parameters: e.g. soil type present, land surface slope, height, aspect, predominant vegetation types expected etc.
- Spectral rules, particularly to help with the interpretation of multitemporal spectral signatures for classification purposes.
- Spatial context rules to refine pixel classes on the basis of their neighbourhood/location in an image and to assist in the generalisation of a pixel-based product to a more cartographically-acceptable structure.

During 1990 experiments have been conducted to improve thematic mapping using the third category of rules noted above as these are the easiest to implement for initial prototype testing purposes.

### Dempster-Shafer Theory of Evidence

One of the key aspects of the work has been the completion of the development of a methodology for handling uncertainty - i.e. for combining uncertain information from multiple sources. It is conventional practice in treating and analysing remotely-sensed satellite imagery to apply classification methods which assign unique class labels to each pixel or segment. For example a classification based on the commonly used maximum-likelihood classifier would select the class of maximum probability based on the multivariate distributions of pixel radiances in feature space.

One of the drawbacks of this approach is that pixels are forced to take a single class label even though in some cases the likelihood values for two different classes may be very close and the maximum likelihood class may not necessarily be the correct one.

Some method of handling uncertainty is therefore required in order not to commit pixels to class assignments which are only vaguely supportable. Since land cover classification is normally done with a hierarchical nomenclature it may in some cases be appropriate to classify pixels at a high-level in the hierarchy rather than at the bottom level. A super-class label (e.g. "permanent crop") may be more appropriate than an individual class label (such as "vines") when there is some degree of doubt. A correct super-class is thematically more useful than an incorrect low-level class.

Since the aim has been to combine traditional statistical classification methods and expert system reasoning it has been necessary to adopt an appropriate method for combining the various pieces of evidence

**1990 Milestones**

| | |
|---|---|
| February | Algorithm using Dempster-Shafer evidential reasoning method ready for operational use |
| September | First results on the use of Dempster-Shafer method to combine spatial context rules and spectral information from satellite data. |

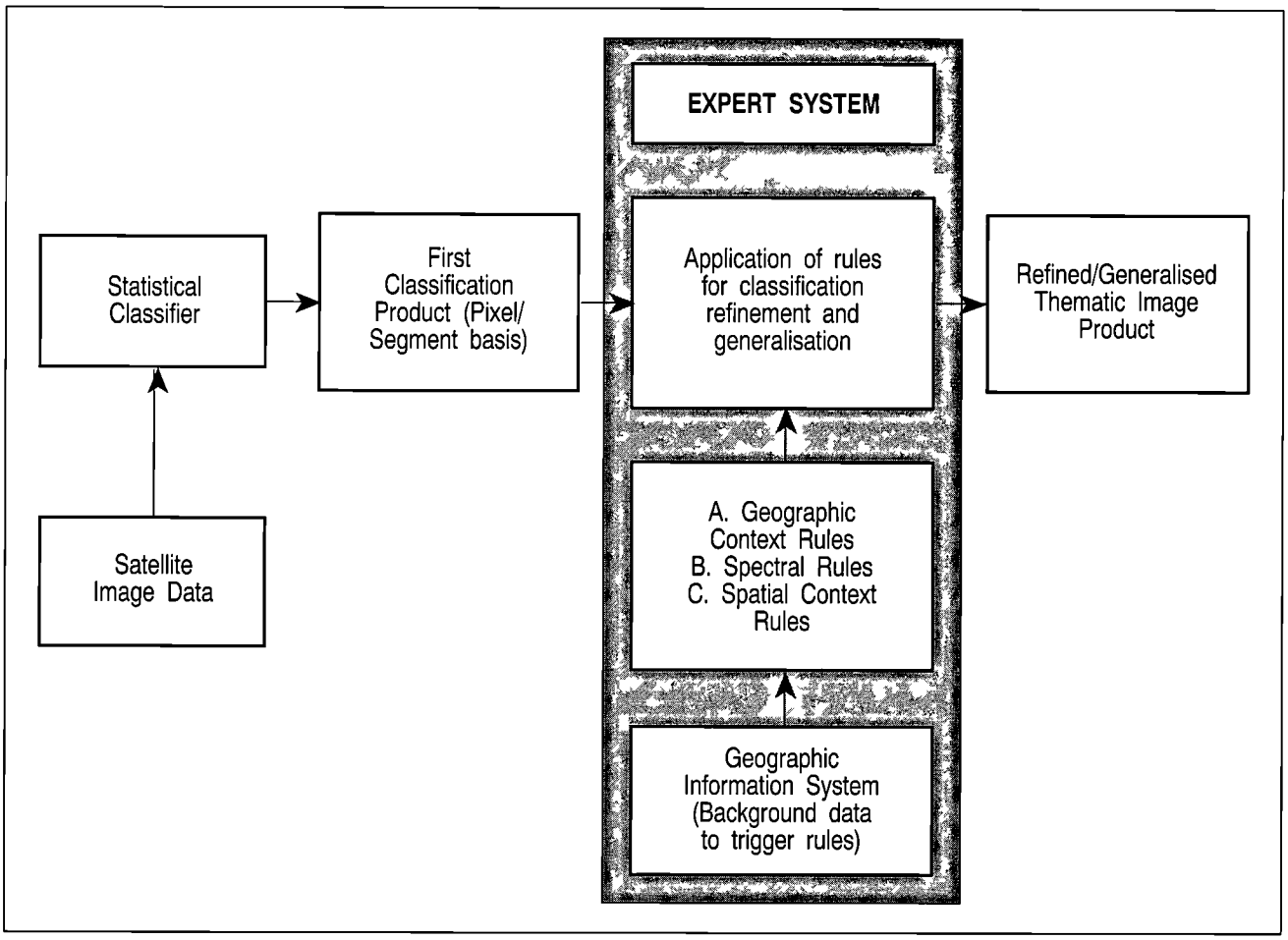


*Fig. 3.5: Expert system for image analysis.*

and to assign suitable classes or super-classes depending on the degrees of support available for them. The numerical reasoning scheme that has been adopted is based on the "belief-function" method of the Dempster-Shafer theory of evidence. In essence individual expert system rules as well as classifiers may provide "degrees of support" (range 0 → 1) either confirming or disconfirming classes or super-classes in the classification tree. These degrees of support may then be combined into "belief" figures for classes and super-classes in the tree.

### Experiments in the Département Loir-et-Cher (F)

A prototype image analysis expert system has been developed to enable the production of improved thematic maps of the main land use classes (primarily agricultural). An initial experiment was conducted for a test area in the Département Loir-et-Cher, France, using SPOT imagery. Initially a classification hierarchy with 15 land cover classes at the bottom level was used and the Dempster-Shafer method was utilized to weigh-up all relevant evidence in classifying pixels. The class or super-class label with the highest belief value was thus identified and assigned to the pixel.

The evidence which was used for this came from three sources:

- a maximum-likelihood classification of imagery into individual classes using spectral signatures;
- a maximum-likelihood classification of imagery into land use super-classes based on a local image variance texture feature and
- an expert system rule base of 38 rules which concern the spatial context of pixels (only a subset of the rules will be triggered for a given pixel).

Each source of evidence (classifier results and triggered expert system rules) provided support figures which were all weighed-up in deriving belief values for the classes and super-classes of the tree for a specific pixel. It was established that initial classification results had an average error of ± 29% at the land-use super-class level. After application of the expert system rules this error was reduced to approximately 18%. The accuracy improvement is therefore in the order of 10%.

A second experiment was undertaken on a smaller purely agricultural test area within the Département Loir-et-Cher using a visual photo-interpretation map as

a source of ancillary information. This was done because the texture variance measure used in the first experiment did not offer much potential for discrimination of individual crop classes.

This pixel based "classification map" based on a single date SPOT image and using spectral information only is very noisy with many isolated pixels. The final classification map after application of the expert system is much less noisy and contains significantly fewer errors. In situations where the evidence is not strong enough to classify at the bottom level the pixel is only assigned a super-class (according to the belief values computed). The final product is much closer in appearance to a thematic map and the improvement in accuracy is about 10%.

Although texture measures and photo-interpretation maps have been used in these experiments it would in practice be possible to use other ancillary data

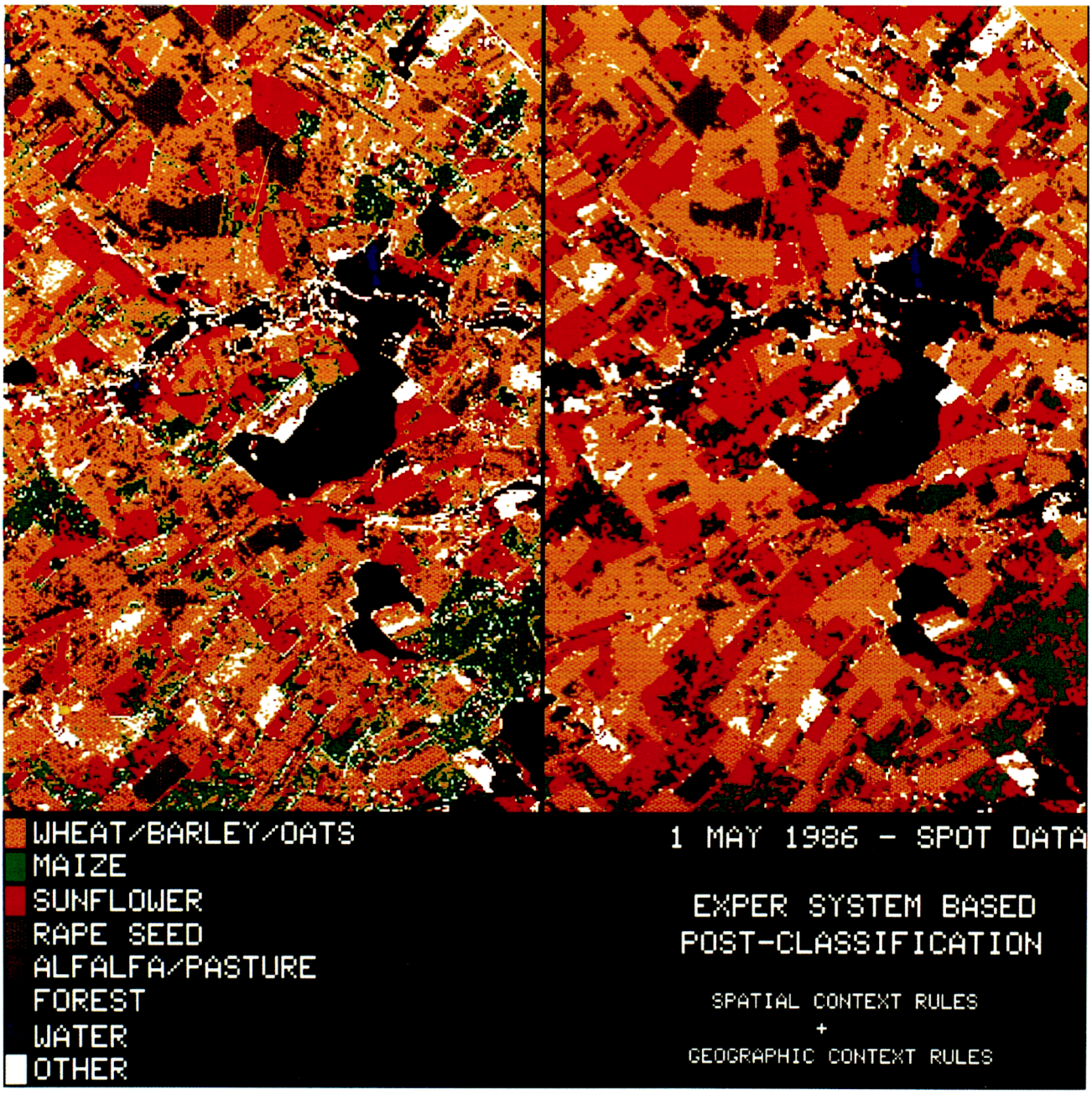


*Fig. 3.6: Illustration of the use of an expert system for improving products from single-date satellite imagery. The image on the left shows an initial classification of a section of a SPOT frame (1 May 1986) over an agricultural area of département Loir-et-Cher, France. The classification was done by a statistical maximum-likelihood approach. The image on the right shows the improved image product derived after additional use of a rule-based expert system integrating image context information and geographic context information extracted from a GIS. Much of the noise and classification error in the original product has been removed by the expert system.*

layers. This could include photo-interpretations or classification results from other image dates. The power of the reasoning method adopted lies in its ability to combine multiple sources of information relating to different levels of a land cover classification scheme. It therefore allows for a very flexible integration of image and geographic evidence for operational applications.

## Conclusion

By developing spatial context rules it has been possible to substantially improve the cartographic quality of classified images yielding both more accurate pixel classifications and more convincing and usable generalised thematic products. The purpose in producing a mixed-level product has been to avoid assigning classes at a low-level where there is insufficient evidence for doing so. In areas where the image pixels or segments can only be allocated to super-classes it can be deduced that extra information is required in order to resolve the individual classes concerned. This may indicate the need for direct human intervention in the processing and the acquisition of extra information sources (e.g. air-photos). This approach therefore enables a more precise definition of the limitations of satellite information.

## Perspectives for 1991

- Continue to develop the method by refining and enlarging the set of spatial context rules applied
- Define and apply sets of background geographic rules and spectral rules with multitemporal satellite imagery
- Link the prototype expert system to the Arc/Info geographic information system
- Extend the use of the method to more operational situations.

# 3.4 INVESTIGATION OF NEURAL NETWORK TECHNIQUES FOR IMAGE CLASSIFICATION IN LAND COVER MAPPING

***Summary of objectives***

- *Investigate the use of neural networks for the analysis of satellite imagery in land cover mapping.*
- *Implement an operational classification algorithm for actual use in land cover mapping applications.*

## 1990 Programme of Work

### Introduction: Preliminary Investigations

An investigation has been undertaken on the use of neural networks for the analysis of satellite imagery for land use applications. Initially a study was carried out of several different kinds of neural networks and on possibilities for their use in multispectral image data clustering and classification. A detailed review study was performed covering theoretical network behaviour and possible applications in operational land use studies using high resolution satellite imagery.

One of the conclusions of this review study was that "forward-feed multilayer perceptron networks" trained by the "backpropagation" algorithm (based on the generalised delta rule of Rumelhart and co-workers) appear to have a potential role in image classification. These networks consist of several layers of interconnected processing nodes: an input layer, one or more hidden layers and an output layer. Each node transforms its input signals into an output by weighting and summing the inputs and applying an activation function.

The basic principle is that if radiance data from a satellite image pixel is applied at the input layer nodes the network computes the correct land use class which is indicated at the output layer nodes. This computation takes place in the successive layers of the net. The network weights must first be trained by a non-trivial iterative procedure so that the network makes an appropriate discrimination between pixels of different classes. In principle such networks are able to provide a significantly more flexible division of image feature space than conventional parametric image classifiers.

### Initial Three Class Problem

An experimental study programme was started on constructing such networks for image classification. Experiments were attempted with both Landsat TM and multitemporal SPOT data. Attempts were made to train multi-layer perceptron networks to recognize specified land cover classes described by training data obtained from ground data.

Early results showed that it was possible to train networks to reliably classify up to 3 ground cover classes. However, attempts with higher numbers of classes were not initially successful because of some difficulties in obtaining convergence in network train-

**1990 Milestones**

| | |
|---|---|
| March | Technical note on the use of the various neural network techniques in satellite image classification. |
| July | First results of the use of a neural network model for a simple three class problem. |
| November | First results for a realistic classification problem using 20 classes. |

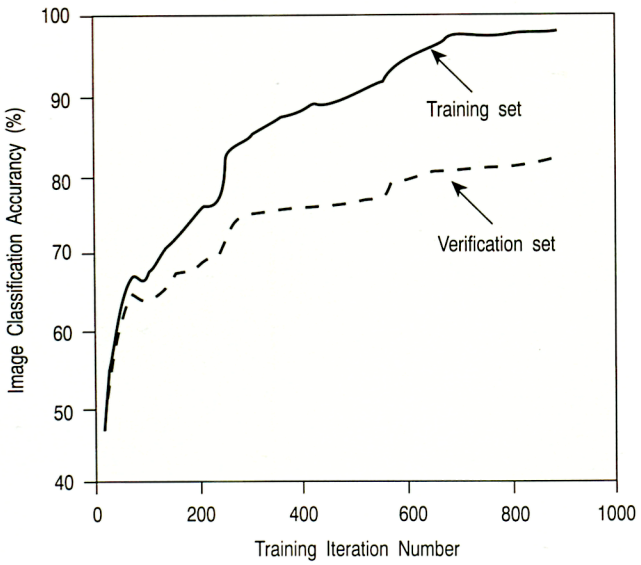


*Fig. 3.7: Increase of image classification accuracy as a 4-layer neural network learns the characteristics of 20 land cover classes in SPOT imagery.*

ing. The experimental work showed that training convergence (i.e. the adjustment of network node connection weights so that classification errors are very small) was highly dependent on:

- the network architecture;
- the volume of training data used;
- the values adopted for the training algorithm learning rate;
- momentum parameters;
- floating point rounding procedures adopted in the computers used for network simulation.

The work in the second half of 1990 therefore concentrated primarily on tackling this convergence problem.

## Further Studies on Improving the Network

A considerable effort was put into the problem by the two Institutes collaborating on this exploratory research (IRSA and ISEI). This work focussed on two new approaches in order to achieve an improved performance in the training phase:

- on improving the node activation functions
- on modifying the standard backpropagation delta rule for learning.

Some work was also started on developing different optimization algorithms to improve the search for a global minimum in the network error, and experiments are still underway on this.

The original sigmoid activation function which has initially been used in the experiments on image classification was then changed to a symmetric hyperbolic tangent function. The activation function is crucial in the learning phase since it controls the sensitivity of node response to input signals. The original function was found to saturate too easily with extreme input values thus making learning difficult. The use of the symmetric hyperbolic tangent overcame this problem and led to much better convergence.

The backpropagation delta rule which forms the basis of the multilayer perceptron networks used in these experiments was also modified. The modification involved:

- removing the momentum term which was found to be difficult to set correctly besides apparently contributing little to convergence and
- "normalising" the learning rate parameter for each different layer in the network because of the differing numbers of nodes present.

This ensured greater uniformity across the network in changing the weights on the interconnections during the training procedure.

## Investigations on a Twenty Class Problem

After these modifications had been made to the backpropagation training procedure it was found that convergence was obtained much more easily. In fact it then became possible to conduct full-scale tests on satellite imagery with a useful number of classes. The first experiments on this have been conducted using two-date multispectral imagery from the SPOT satellite over the Département Ardèche in southern France. A test area was chosen near the town of Les Vans with field survey information coincident with the imagery. These field data were used both to train a network and to test its performance at classification.

The ground data for this imagery had a total of twenty classes. These were mostly various types of agricultural crops.

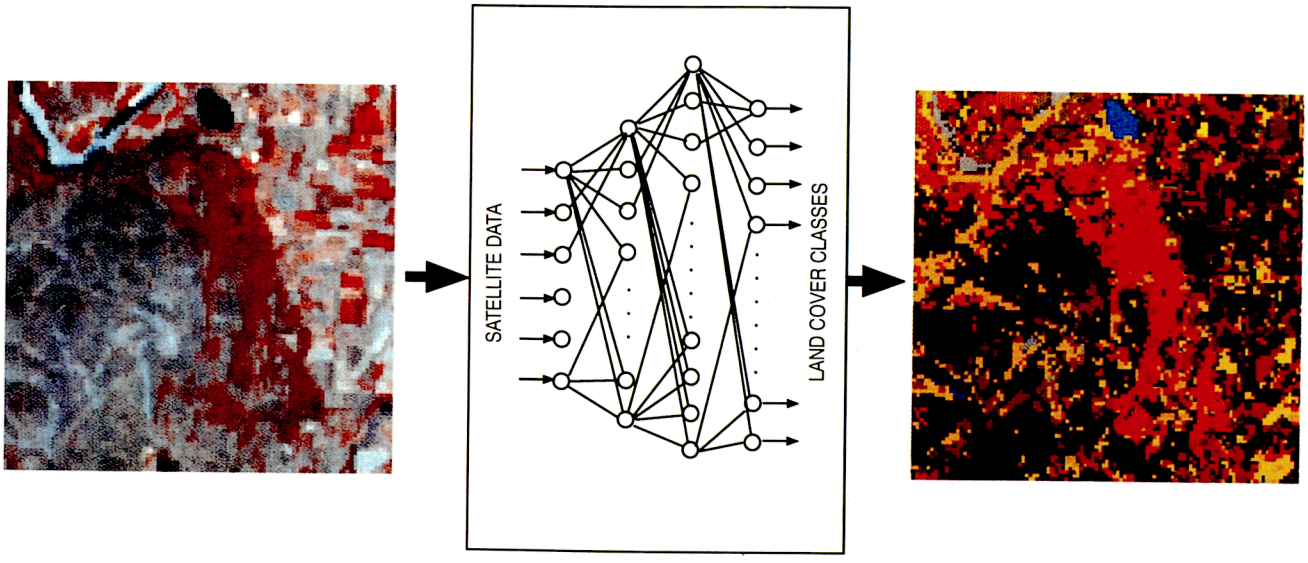


*Fig. 3.8: Image classification by neural network.*

A network was trained using this data on a SUN-4/260 workstation. In total approximately 3800 training pixels were used covering the twenty land cover classes. It was found that for a problem of this complexity a fairly large network architecture was required with:

- 6 nodes in the input layer;
- 15 in a first hidden layer;
- 41 in a second hidden layer;
- 20 in the output layer.

This network was fully-connected and therefore contained 1525 separate connections and the same number of weights (all of which have to be adjusted in training). Overall it was found that of the order of 600 iterations were required to reduce the network error to a suitable value to give a good classification. This took approximately 9 hours to execute on the SUN workstation.

After the training procedure had been carried out the full SPOT image dataset was classified using the derived network weights. The results of this were evaluated using the ground data and they appear to be encouraging. The average classification accuracy achieved over all the 20 classes was 83.2%. This level of accuracy competes very well with the performance of traditional parametric statistical classifiers and may also exceed the capability of the traditional methods with such high numbers of classes, although more work is still needed on comparisons.

## Conclusions

After one year of work on this activity it is possible to conclude that as a pattern recognition or classification tool in remote sensing the neural network approach has much to offer. It can be stated unequivocally that it is now possible to obtain image classification results at least as good as can be obtained with more traditional methods. The challenge for the future will be to see how far the technique can be extended for use in operational applications.

## Perspectives for 1991

- Extension of the studies on larger areas;
- Improvement of the optimization technique with new search procedures;
- Test of a set of hierarchical networks instead of a unique global network;
- Comparison of neural network with maximum likelihood and expert system classifiers on the same set of data;
- If possible, implementation of the method on a parallel computer.

# 4 MARINE ENVIRONMENT

*Contact:* P. Schlittenhardt

## Staff

| | |
|---|---|
| Scientific and Technical Staff | 11.75 |
| Secretarial Support | 1.0 |
| Students | 0 |
| Visiting Scientists | 2.0 |
| Detached Experts | 0 |
| Total | 14.75 |

## Publications

| | |
|---|---|
| Journal Papers | 1 |
| Conference Papers | 12 |
| JRC Reports | 0 |
| Books / Chapters | 0 |
| Total | 13 |

## Facilities

- Vax 4000 with ERDAS image processing software (including software developed in-house for CZCS and AVHRR data processing).
- PC's with ERDAS and in-house image display.
- SUN Sparc stations for CZCS data archive and data processing.

The scope of this Unit is to demonstrate and validate methodologies for the practical use of data from space and airborne sensors in both operational applications and scientific investigations related to the marine environment. In order to undertake this overall objective three activities have been defined:

- Ocean Colour European Archive (OCEAN): Large scale, long term ocean colour data represent a vital source of information for understanding biogeochemical and physical processes in the sea. A considerable time series of ocean colour data, covering all the major European basins, was collected by the Coastal Zone Colour Scanner (CZCS) on board the satellite Nimbus 7 from 1978 to 1986.
  Although preliminary work on CZCS data has demonstrated the usefulness and potential of this data set, only limited efforts have been made in Europe to fully exploit the potential information. As a result a joint IRSA/ESA initiative has proposed to compile a catalogue of all data available in Europe for use in demonstration projects towards an understanding of ocean and coastal waters.
  The project is carried out in support of Directorate General XI.
- Coastal Upwelling Off The Coast Of West Africa: The goal of this activity is to investigate the capabilities of satellite remote sensing data for the study of coastal upwelling off the north west African coast. Well developed trade winds bring cold nutrient rich water to the surface resulting in high biological activity.
  Such water masses are characterised by low temperature and high phytoplankton content, two properties which may be observed by remote sensing satellites. A better understanding of this phenomenon and its dynamics may eventually be used to evaluate resources and identify fish stock requirements.
  This activity is carried out in support of Directorate General I and in collaboration with institutes in Morocco.
- Global Change - Marine Biosphere Atmosphere Interaction: This new project will study possible areas where the Institute could actively contribute to marine global change programmes.

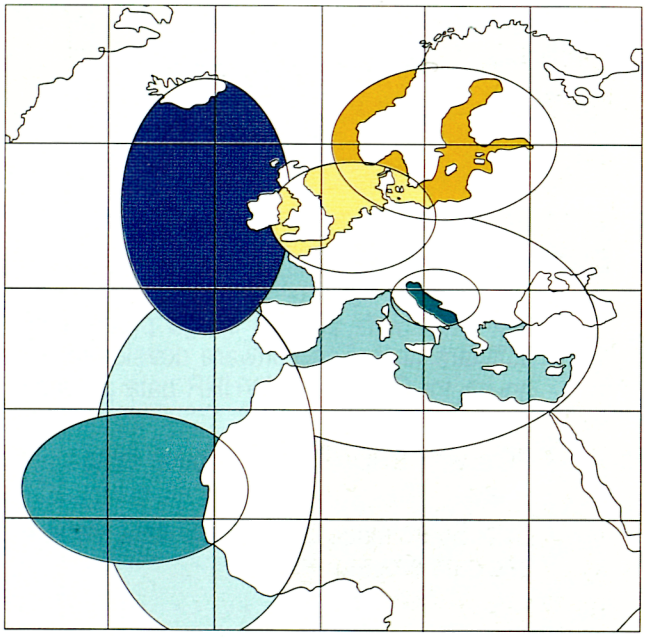

*Fig. 4.1: Sea areas covered by the OCEAN project.*

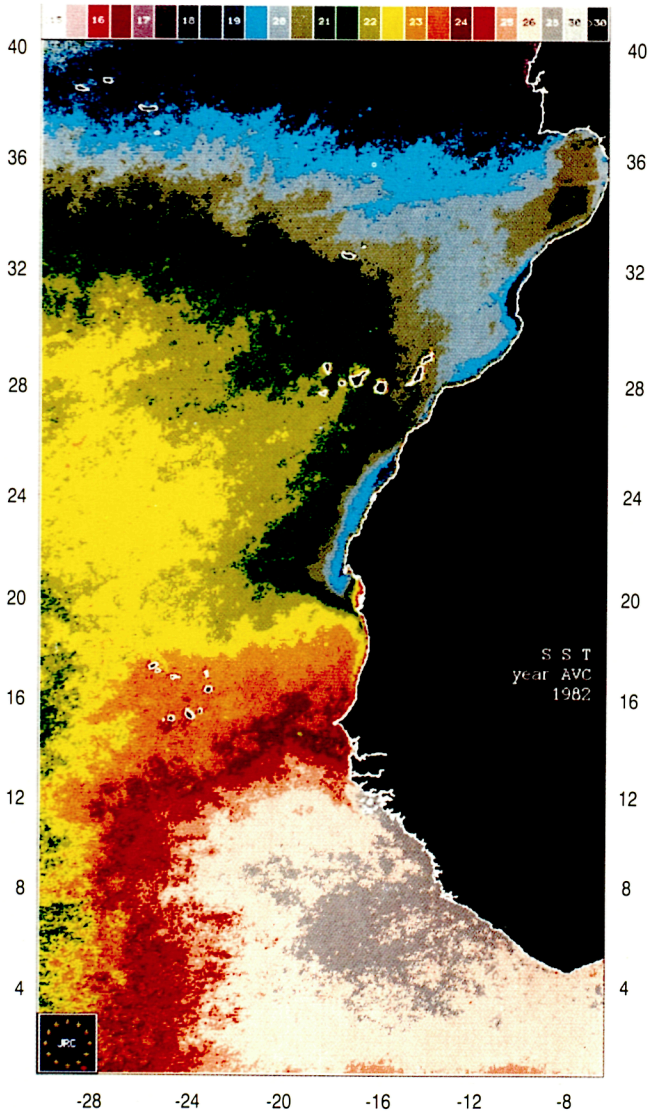


*Fig. 4.2: An example of a yearly map of SST for 1982 as observed from remote sensing data, and derived by averaging the monthly maximum value composites. The initial input to this yearly map consists of about 350 daily SST maps.*

# 4.1 CONTRIBUTION OF MARINE STUDIES TO THE ANALYSIS OF GLOBAL CHANGE

***Summary of objectives***

- *To develop, and to extend where possible, algorithms that relate variables available from remote sensing, ocean platforms and ship surveys to processes occurring in the water column such as heat flux and primary productivity.*
- *To generate, archive and analyze multiannual time series of satellite derived observations and other related meteorological and in situ data.*
- *To assimilate satellite data in local and regional models for process studies and for contributions to global models.*

## 1990 Programme of Work

### Introduction

Global Change studies involve the interactions between the physical, chemical and biological processes that regulate the Earth system and that are most susceptible to human perturbation. The system comprises the atmosphere, land, oceans and the biosphere. The two major international programmes focussing on the study of Global Change are the International Geosphere Biosphere Programme (IGBP) of the International Council of Scientific Unions (ICSU) and the World Climate Research Programme (WCRP) of the World Meteorological Organization (WMO). Thus the participation by the Institute for Remote Sensing Applications should provide contributions to the research objectives of these international programmes. The activities to be proposed should, therefore, build upon the expertise and competence already available within the Institute in the area of the marine environment.

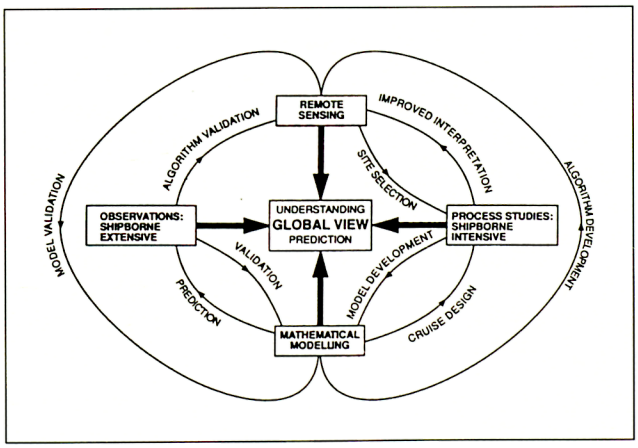


*Fig. 4.3: The interactions between the various components of JGOFS.*

**1990 Milestones**

- Completion of initial planning for calibration campaign of the Along Trade Scanning Radiometer (ERS-1)
- Evaluation of ocean colour data for modelling biological productivity.
- Integration of these studies in International Global Change Programmes (JGOFS, WOCE)

Three activities are particularly relevant to global studies:

- Sea-surface temperature and marine heat flux. The new European satellite ERS-1 whose launch is planned for 1991 will provide improved data through the Along Track Scanning Radiometer (ATSR), which should deliver temperature measurements with higher accuracy's than from instruments flown on earlier satellites. An experiment is planned the objective of which is to calibrate the new sensor in a sea region of interest to WOCE and where the Institute has been performing sea surface temperature studies using AVHRR since 1981
- Marine primary production and ocean colour. On the basis of the Institutes experience with ocean colour data derived from the Coastal Zone Colour Scanner (CZCS) for the estimation of phytoplankton biomass, a collaboration has been formed with a number of Institutes working in the framework of the JGOFS programe on the estimation of oceanic primary production in the eastern North Atlantic. Satellite imagery for testing and validating the techniques will come from the proposed Ocean Colour European Archiving Network (OCEAN) project.
- Modelling related to marine processes and remote sensing data assimilation. To gain a clearer understanding of complex physical and biological inter-

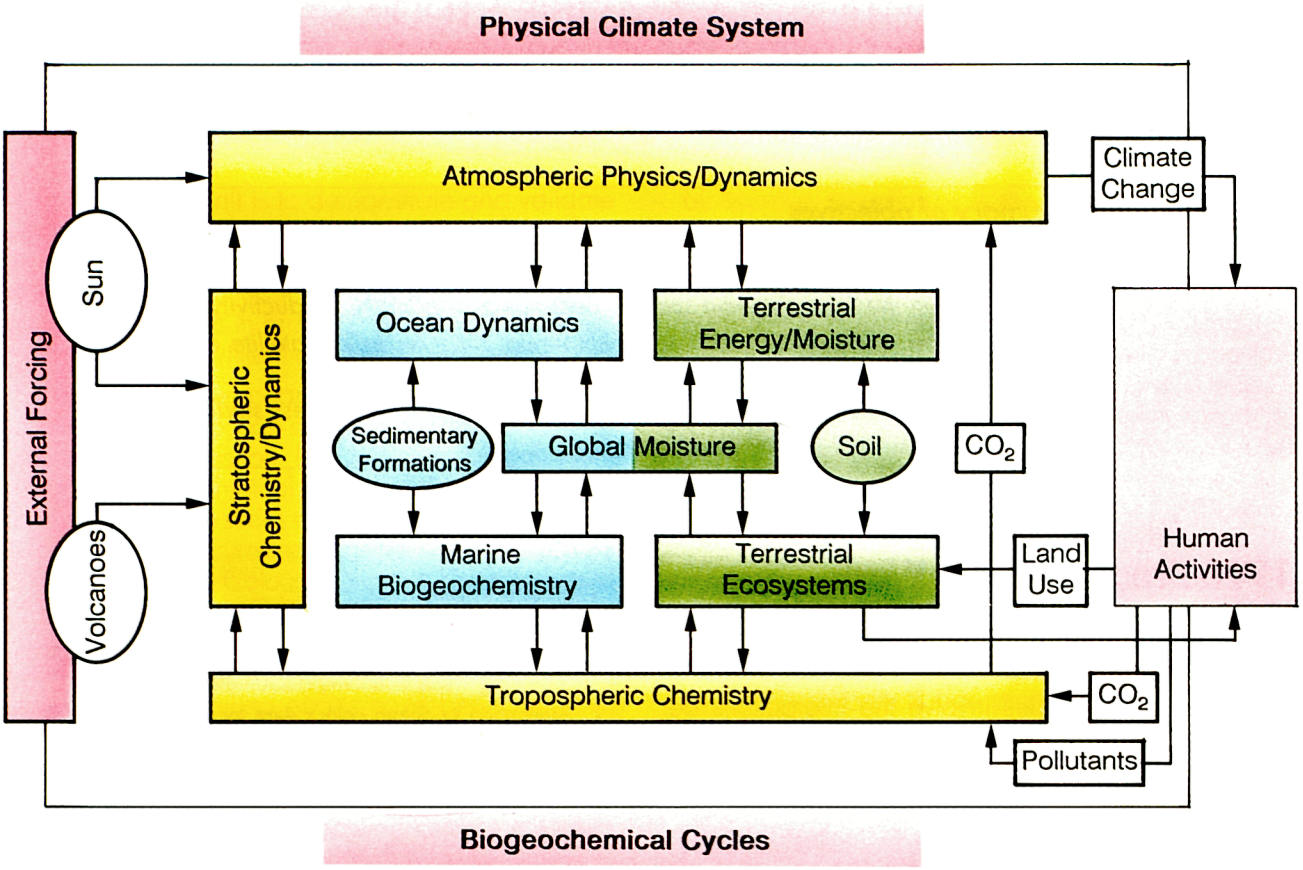


*Fig. 4.4: Conceptual model of global system.*

actions occuring in selected marine areas (eastern north Atlantic), regional process models are being developed. A long-term goal is to develop techniques within these models which will allow the assimilation of synoptic parameters provided by satellite earth observations and in-site oceanographic data. The techniques will use the major data archives available in the Institute for analysis of long-term parameter trends.

## Sea Surface Temperature and Marine Heat Fluxes

An accurate prediction of the latent heat and sensible heat fluxes at the air-sea interface is of major importance for a wide range of studies including simulations with large-scale coupled ocean-atmosphere models, weather forecasting, and diurnal to annual variations of the upper oceanic layers.

Satellite infrared sensors only observe the temperature of the skin of the ocean rather than the bulk sea surface temperature (SST). Most oceanographers, however, are interested in SST more representative of the upper meters of the oceans. The difference between skin and bulk temperature contributes to an added level of uncertainty in satellite SST data.

The Institute is presently planning, in collaboration with other European institutes, a study being undertaken in the framework of WOCE, on air-sea energy fluxes and skin sea-surface temperature as observed by the ATSR on ERS-1 in the north east Atlantic under summer environmental conditions.

## Marine Primary Production and Ocean Colour

In the oceans, as on the land, a fundamental biological process is the photosynthetic fixation of carbon; the rate of photosynthesis is equivalent to primary production. Although it is the principle source of organic carbon for the support of the entire marine ecosystem, the magnitude of primary production in the ocean is still disputed to within a factor of ten. This large uncertainty continues to confound speculation on such important questions as whether oceanic plankton will serve as a significant sink for the $CO_2$ that is building up in the atmosphere.

The advent of remotely-sensed data on ocean colour has made the synoptic estimation of primary production for entire ocean basins an attainable goal.

More precise estimations of primary productivity using ocean colour data also require bio-optical models as surface input. These must be further developed to more realistically account for biomass

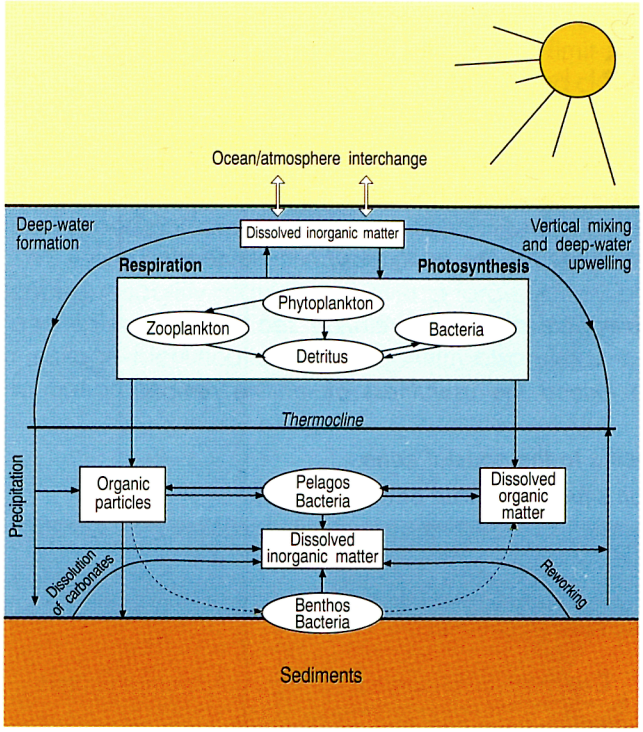


*Fig. 4.5: Primary production: the starting point of the organic flux.*

distribution throughout the euphotic zone at the local level, and methods must be chosen to allow extrapolation over large spatial scales.

The estimates of water column production will be made using a coupled one dimensional bio-physical model in which the photosynthetic response of phytoplankton to available light is parameterised in terms of known physiological parameters. The underlying physical model will supply an essential parameter, namely, the mixed-layer depth.

The studied area can be partitioned into a limited number of zones within which the essential biological properties (pigment profile, photosynthetic parameters) can be considered. It is likely that one of the best guides to delineate these biogeochemical provinces will be the satellite images themselves. The daily rate of production will then be integrated over each province, and over seasons and years as required.

## Modelling Related to Marine Processes and Remote Sensing Data Assimilation

To gain a clearer understanding of complex physical and biological interactions occuring in selected marine areas (eastern north Atlantic), regional process models are being developed. A long-term goal is to develop techniques within these models which will allow the assimilation of synoptic parameters provided by satellite earth observations and in-site oceanographic data. The techniques will use the major data archives available in the Institute for analysis of long-term parameter trends.

Within these overall objectives the following medium-term goals have been identified for developing the modelling activity:

- to describe mathematically how remotly sensed sea surface conditions are linked to upper layer bulk processes.
- to provide fluxes (heat, trace gas etc.) at the sea-atmosphere interface based on remote sensed data for global change applications.

In view of these objectives it is clearly necessary to pay special attention to the modelling of both the interface related phenomena and the interrelated bulk processes. As a working tool a computer programme is being set up to describe the regional ecological system for the Marine Environment Unit's application area, i.e. the Eastern North Atlantic including the North-West African upwelling area.

This approach has been developed from modelling work started at JRC in 1988 in the framework of the remote sensing activity "Coastal pollution dynamics" referring to the Adriatic as application area. Based on the experience gained in this period, careful examination of available hydrodynamic models is being undertaken.

## Perspectives for 1991

For the test site in the North-East Atlantic, a hydrodynamic model will be initiated for typical idealized shelf geometries to evaluate the relative importance of wind stress, shelf geometry and latitude on upwelling and productivity.

On the basis of the data archives of the Marine Environment Group, the variability of multi-annual time series sea surface temperature will be investigated in relation meteorogical data.

It is espected that closer contacts will be developed with the International programme Joint Global Ocean Flux Study (IGBP-JGOFS)

# 4.2 COASTAL MONITORING

***Summary of objectives***

- *Development and improvement of methods for the analysis of remote sensing data on sea colour.*
- *Development and improvement of bioptical algorithms relating sea colour to water composition.*
- *Search for new applications which extend the usefulness of marine remote sensing.*
- *Study of small-scale phenomena specific to the coastal zone.*
- *Monitoring of typical coastal pollution situations (state and dynamics).*

## 1990 Programme of Work

### Introduction

The usefulness of specific applications of remote sensing to coastal waters has been investigated. Three studies, referring to the use of TM, AVHRR and CZCS sensors, respectively, are summarized in the following paragraphs.

### An Algorithm for the Detection of Mucilage (Green Slime) in the Adriatic Sea

In summer 1989 an abnormal production of mucilaginous matter occurred in the northern basin of the Adriatic Sea. This substance eventually came afloat, forming extensive banks driven around by winds and currents. The phenomenon was particularly remarkable along the Italian coast of the province of Rimini, an area with one of the highest concentrations of tourist resources in Europe.

The identification of this "mucilage" by remote sensing techniques, besides being clearly useful for the timely organization of appropriate safeguard measures, may also help to identify the cause of the phenomenon, if the frequency of the remote measurements is high enough to monitor the dynamics of the event.

The fine ground resolution of the Thematic Mapper (30X30 $m^2$ pixel) allows the discrimination of mucilage from clouds as well as a detailed display of the mucilage structure. Unfortunately the LANDSAT 5 cycle, with a repetition rate of one pass every 16 days, is not adequate for monitoring this phenomenon in time.

The Advanced Very High Resolution Radiometers (AVHRR) on board NOAA 10 and 11 cover the same zone of the Earth twice a day (in daylight), providing time series of considerable value. On the other hand, the low resolution (1 $km^2$ pixel at nadir, 4x7 $km^2$ tpixel

### 1990 Milestones

December: ENEA commits study of algal coverage of Venice Lagoon by Thematic Mapper.

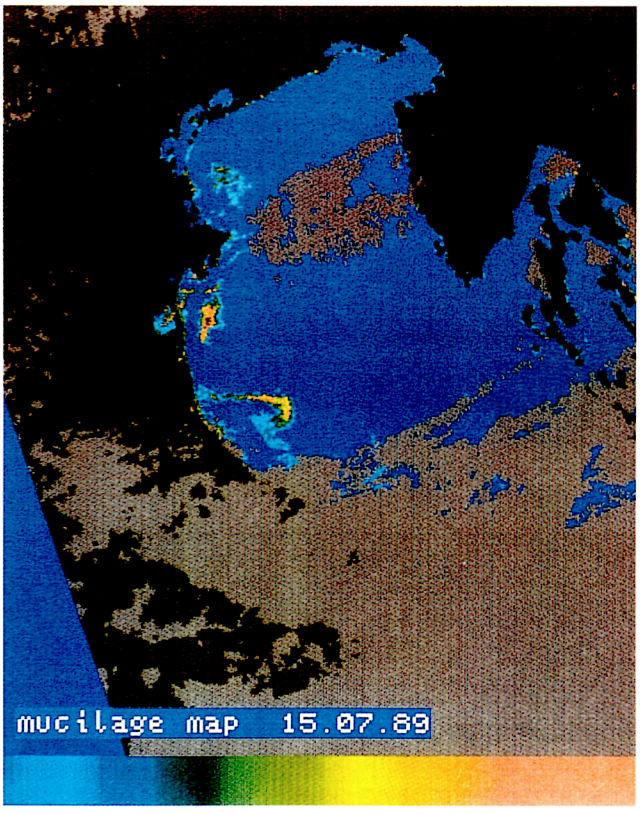


*Fig. 4.6: Map of the "mucilage" banks in the Adriatic sea, derived from AVHRR data recorded on July 15 1989.*

at the swath edge) and the coarse spectral information (2 broad bands in the VIS-NIR range) limit the sensor capability of mucilage identification and cloud discrimination.

An algorithm for mucilage detection using AVHRR data and including a cloud-screening routine was developed and tested versus sea-truth provided by a TM scene. The algorithm seems to meet the prescribed reliability requirement over a large variety of atmospheric conditions. Apart from providing for mucilage identification, the algorithm also yields information on the mucilage density.

Fig. 4.6 shows the mucilage map derived from the AVHRR data recorded on July 15,1989. Land is masked in green, cloud and thick haze are masked in grey. Mucilage is displayed according to the attached colour code, with density increasing from left to right.

The small computational effort required for the data analysis makes the procedure suitable for operational use. Transmission of the mucilage maps derived from the AVHRR data to concerned authorities can be performed within a short time (about 1 hr) from the recording of the data by the Tiros antenna.

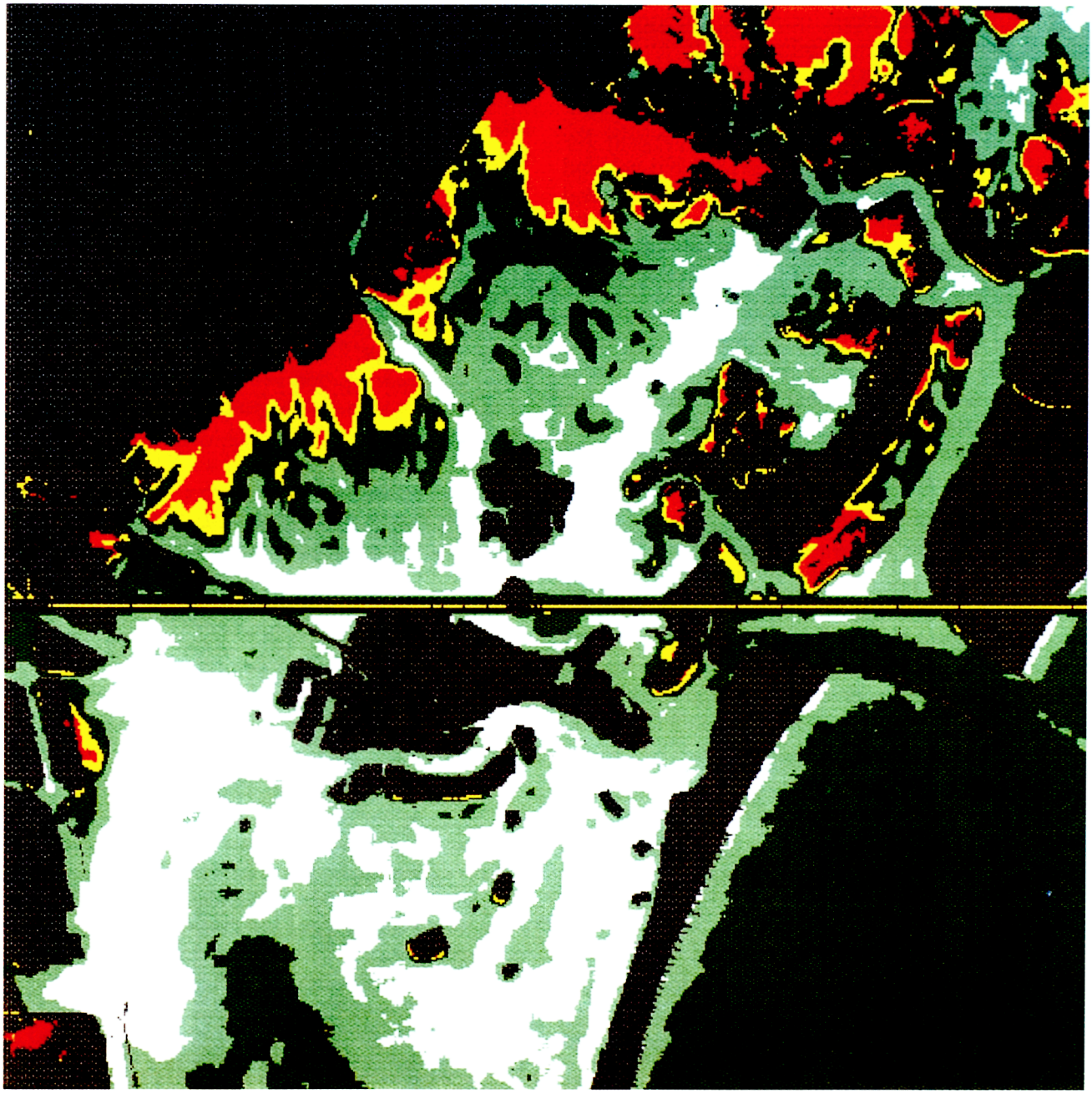

*Fig. 4.7: A Thematic mapper image showing algal coverage in the Venice Lagoon (recorded on June 7 1989). The land is shown as brown, deep algae are in varying shades of green and floating algae are in red.*

The algorithm for mucilage identification from AVHRR data can be developed into a software package to be proposed as a tool for monitoring the water quality in the Adriatic Sea.

### An Algorithm for the Identification of Benthic Algae in the Venice Lagoon from Thematic Mapper Data

The progressive eutrophication of the Venice lagoon, due to intense urban and industrial pollution, has caused a considerable increase in the diffusion of benthic algae belonging to the group ULVA RIGIDA, C., Ag. This causes disturbance to the residents, requiring frequent removal of the algal masses by mechanical means.

Monitoring of the algal coverage dynamics by remote sensing techniques supplies a source of information which is synoptic, readily available and relatively inexpensive.

The Thematic Mapper (TM) scanner, orbiting onboard LANDSAT 5, has the potential to yield detailed maps of algal coverage, due to its fine ground resolution (30x30 $m^2$ pixel) and to the suitable distribution of the radiometer bands in the VIS-NIR range.

An algorithm for the identification of benthic algae in the Venice lagoon, using Thematic Mapper data corrected for the effects of the atmosphere, has been developed from a study combining water optics modelling with remote sensing procedures. The algorithm has been applied to the TM scene recorded on June 7, 1989 and satisfactorily tested versus experimental data on algal coverage collected in-situ.

The algorithm does not require auxiliary in-situ experiments at the time of the LANDSAT overpass, and operates in an unsupervised mode with automatic classification of the bottom type.

The algorithm for classification of algal coverage has been applied to four TM scenes of the Venice Lagoon (Work performed under contract for ENEA, Rome, Italy).

### Detection of Industrial Waste Disposal in the German Bight from CZCS Data

As one of the most exploited marine regions, the North Sea is exposed to increasing marine pollution. After the dangers for the marine eco-systems have been recognized protective measures have been set up both on national and international levels. Such measures are most important in the case of the German Bight which accumulates pollutants because of its low water exchange rates. Additional to the pollutants from local river out flow and waste disposal the coastal currents bring pollutants from other parts of the North Sea into the German Bight. Because of the low water depth, strong tidal currents and frequent storms the pollutants are not deposited in the sediment but remain suspended in the water column.

The usefulness of satellite ocean colour remote sensing from Nimbus-7 CZCS was evaluated for the detection of waste products from the Titan dioxyd production ("Dünnsäure") discharged into the sea.

The evaluation of 22 CZCS scenes from April 1979 to July 1983 showed that the discharged material has a characteristic spectral signature due to the increase of the water leaving reflectance, especially strong in band 3 (550 nm) of CZCS. The discharged plume remains visible for at least 80 hours and its contrast reaches a maximum at a couple of hours after the end of the discharge. The combined action of tidal currents, density fronts and wind on the plume results in displacement from the discharge area in a north-west direction.

### Perspectives for 1991

work will continue on specific algorithm development for case by case studies.

# 4.3 STUDY OF THE NORTH WEST AFRICAN UPWELLING AREA (Supported by DG 1 External Relations)

***Summary of objectives***

- *Application of remote sensing for studying coastal upwelling off Northwest Africa*
- *Time series analysis of SST from space and development of relevant methodologies*
- *Quantitative analysis of dynamics of chlorophyll patterns observed from CZCS*
- *Preprocessing of relevant archives (SST, wind and chlorophyll)*

## 1990 Programme of Work

### Introduction

During 1990 the study of coastal upwelling along the Northwest African coast has been directed towards the use of longer time series of satellite images. This has been recognized as being the most efficient way of extracting useful information for physical and biological studies. A major effort has been invested into the production of long time series of daily sea surface temperature (SST) images and meteorological data for the Central East Atlantic Ocean.

In parallel the work during 1990 concentrated on: (i) quantitative analysis of SST time series as well as cross-correlation analysis of CHL images derived from CZCS (Coastal Zone Colour Scanner) data, (ii) evaluation of a major vector GIS (Arc/Info) for facilitating spatial integration and analysis, (iii) development of sophisticated land/sea/cloud identification software, (iv) testing of the whole AVHRR module, (v) development of the completely new CZCS software running in the ERDAS image processing environment.

Part of the study is carried out in close collaboration with l'Institut Scientifique des Pêches Maritimes (ISPM) in Morocco.

### Cooperation with ISPM, Morocco

Evaluation of the marine resources, which constitutes the main occupation of ISPM, requires a profound knowledge of the marine environment and in particular of the coastal upwelling dynamics. Traditionally the marine environment has been studied from in-situ measurement campaigns, which provide data that are difficult to extrapolate in time and space. The use of remote sensing data in conjunction with in-situ data is believed to be a key approach for understanding the time and space variation of coastal upwelling. JRC and ISPM have therefore established a scientific collaboration for the application of remote sensing data to the Northwest African upwelling area.

**1990 Milestones**

- Continuation of the NOAA/AVHRR/GAC archive processing into SST maps
- Production of SST colour hardcopy catalogues
- SST time series analysis
- Assessment of coherency between CZCS images
- Design and implementation of the CZCS software
- Marketing agreement of the AVHRR software
- Benchmarking of GIS Arc/Info

For the period 1990-1992 the following objectives are to be realized: (i) examination of all CZCS CHL images covering the area, integrated with other information used for fishery management purposes, (ii) establishment of a coherent view of the temporal and spatial variability of coastal upwelling with the use of NOAA/GAC/SST images, (iii) integration of meteorological data for the interpretation of satellite imagery, (iv) collection of in-situ data along the Moroccan coast including current measurement, (v) realization of specific in-situ measurements at Cape Ghir to further study the filaments observed in satellite images at that location.

Furthermore the JRC will assist ISPM in: (i) developing in-house expertise in the application of remote sensing, (ii) carrying out feasibility studies for specific applications such as mapping of macro algae and potential sites for aquaculture.

### Time Series of GAC SST Data

The complete AVHRR/GAC archive was processed into daily SST maps for the Atlantic Ocean from 0-40° N and from 6-30° W.

The archive at the JRC covers the period from 1 July 1981 to 31 August 1989. The total amount of SST products is 3300 or about 33 images per month. As

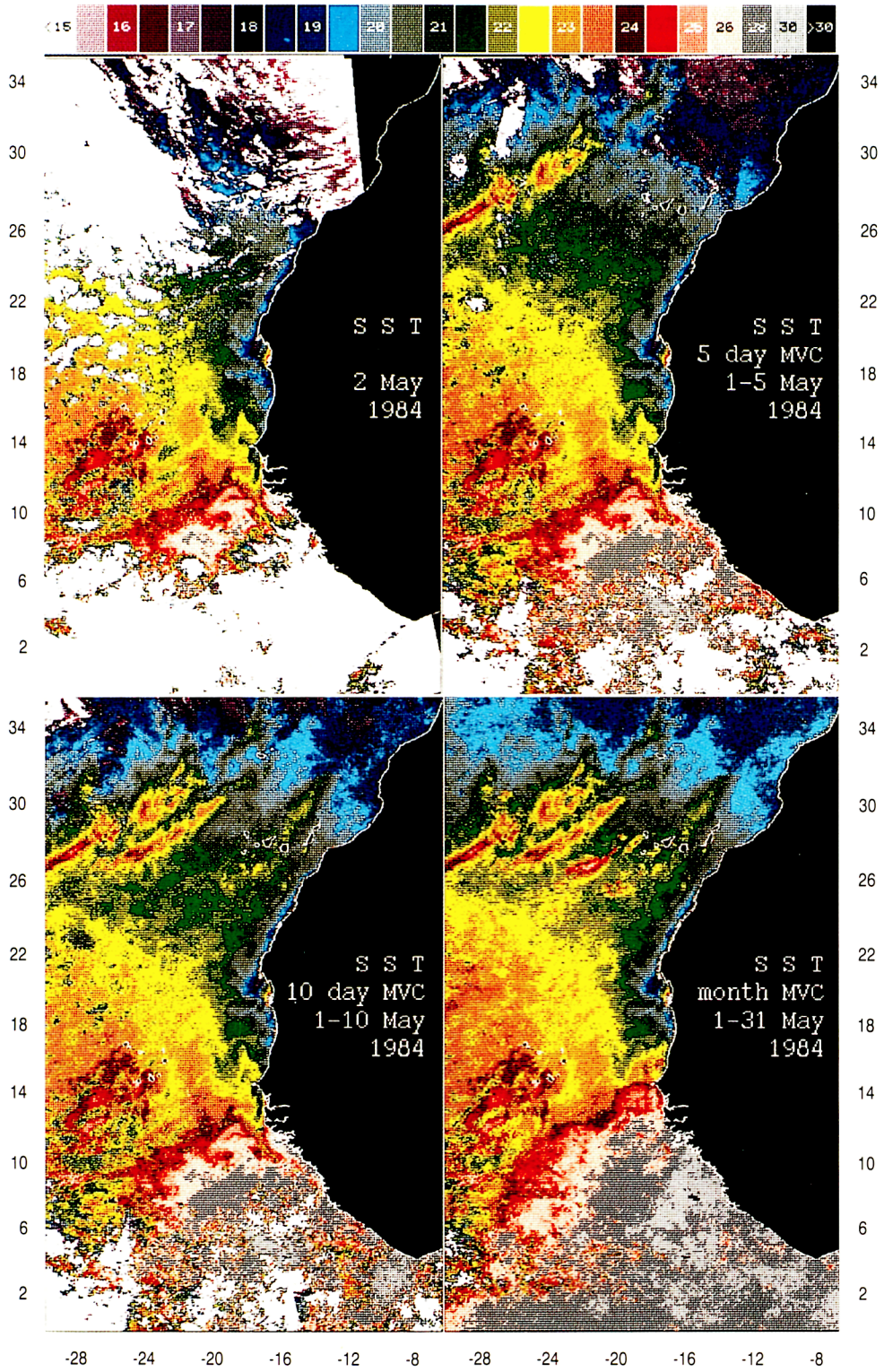


*Fig. 4.8: Typical examples of mapped sea surface temperature (SST) products as derived from the NOAA/AVHRR/GAC archive: (a) daily SST map, (b) 5-day maximum value composite (MVC), (c) 10-day MVC and (d) monthly MVC.*

part of the operational processing 5-day, 10-day and monthly maximum value composites have also been generated, thus obtaining quasi cloud free composites. In addition hardcopy catalogues of all SST products and composites have been generated.

The processed SST archive, both daily products and composites, constitute an ideal data input for long term ocean and cloud studies. This archive is being used for the study of the seasonal and yearly variability of the Atlantic ocean with special emphasis on the Northwest African upwelling area for which the SST is a clear indicator. In addition the archive of daily SST has been used to extract input data for the neural network exploratory research project. The SST products are also to be used within the global change project.

## Time Series Analysis

The SST monthly maximum value composites were used for generating yearly SST composites based on averaging. Each of the yearly composites is eventually based on an input of about 400 daily images. The averaging represents an enormous data reduction while maintaining a wealth of information. The yearly averages are used to study the yearly and geographical variability of SST in the area.

SST values for selected locations in the upwelling area have been extracted from both the daily images and the monthly maximum SST composites. The temporal variability of the SST is then displayed in graphical profiles for the daily SST and monthly maximum SST.

The graphical profiles present information complementary to the SST images in the sense that they highlight the temporal SST variability for a specific location, while the images represent the geographical variability for a selected period. In the graph the large day to day variability of SST is remarkable. Nevertheless the yearly repeat cycle of monthly maxima is easily recognized.

Analyses of sequential satellite images have been carried out in order to estimate the decorrelation time of surface patterns at different spatial scales. The analysis has been applied to CZCS chlorophyll pigment concentration images covering the area off Cape Blanc, however the same technique has to be applied to AVHRR SST images before a final conclusion can be made. The patterns observed in sequential pairs of satellite images are believed to represent well near surface velocities. Therefore an objective pattern matching method based on maximum cross-correlation between pairs of sequential satellite images has been developed and applied.

## Enhancing and Testing the AVHRR Software

A major addition to the AVHRR software is a set of components for land/sea/cloud identification. The method consists of several successive steps: (i) calculation of the satellite derived albedos and true brightness temperatures, (ii) determination of sunglint (based on sun and satellite zenith and azimuth angles) (iii) cloud/land/sea discrimination.

Depending on the AVHRR bands available, on the presence or absence of sunglint and on the time of the pass, a set of tests is performed for the land/sea/cloud discrimination: (a) gross cloud

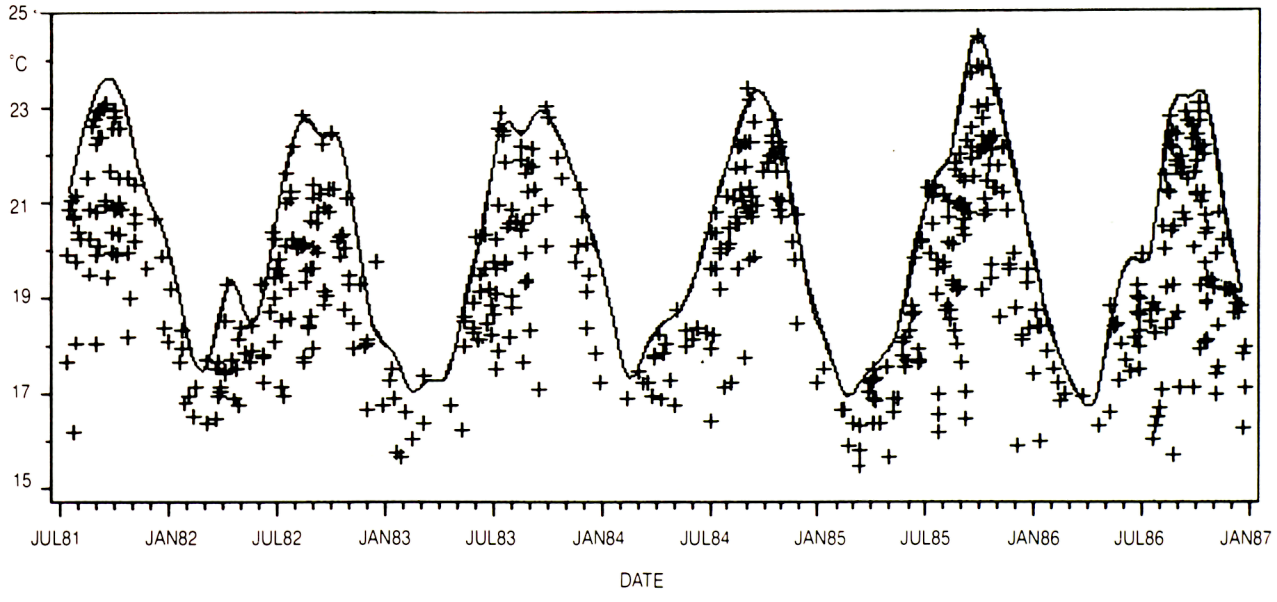


*Fig. 4.9: Day to day variation of the sea surface temperature (+) and variation of the monthly maximum sea surface temperature (-) in the open ocean at 33°N 14°W, observed from Infrared satellite data.*

check, (b) land/sea discrimination, (c) thick cloud test, (d) fully clouded pixels, (e) thin cirrus test, (f) fog/low stratus test, (g) medium/high level clouds and (h) spatial coherence test.

## CZCS Software Development

A complete package for processing CZCS data has been developed in the ERDAS environment. This package represents the many years of experience that JRC has in processing CZCS data contained within one single environment. The package is developed in the "C" programming language and is considerably more compact and faster than previous CZCS software.

The major improvements that have been undertaken are the ability to perform geometric correction with combined earth location points and ground control points, the implementation of the CIA world data base II for annotation, the limited need of components accessing the tape units.

The CZCS software is also now available in the commercial image processing environment.

## Perspectives for 1991

- Identification of SST anomalies and their relation to large scale wind variations
- Comparison of seasonal SST maps from space to atlases of SST and meteorological parameters
- ATSR validation study for characterizing the heat fluxes in the ocean/atmosphere boundary layer.

# 4.4 OCEAN COLOUR EUROPEAN ARCHIVE NETWORK (OCEAN) PROJECT (In Support of DG X1 Environment)

***Summary of objectives***

- *Use of colour data over seas of European concern, for an improved understanding of marine environmental issues;*
- *Organize a reliable, well documented, easily accessible archive of historical CZCS-derived ocean colour data;*
- *Develop advanced methodologies and algorithms for the derivation of geophysical parameters from ocean colour assessments;*
- *Generate CZCS value-added data and promote their use in suppport of current research and future ocean colour missions.*

## 1990 Programme of Work

### Introduction

The Ocean Colour European Archive Network (OCEAN) Project, an initiative of the Institute for Remote Sensing Applications (IRSA) and of the Earthnet Program Office (EPO) of the European Space Agency (ESA), has been established to perform a thorough reappraisal of all Coastal Zone Colour Scanner (CZCS) data covering marine regions of European concern. The underlying theme of the Project is the full exploitation of available CZCS data in an application demonstration programme, for an improved understanding of marine environmental issues.

Activities related to the OCEAN Project were started during the first quarter of 1990, following an ad hoc meeting of the OCEAN Project Expert Group (composed by a number of European scientists involved in ocean colour research, as well as by JRC and ESA personnel). The initial phase of the OCEAN Project has approached the task of preparing the proper tools needed to use ocean colour data for environmental applications. The work carried out concerns the generation of an European CZCS data catalogue, as well as the definition and preparation of hardware/software environments, of new data archive formats, and of improved data processing algorithms.

### Development of OCEAN Systems and Algorithms

The definition of the hardware environment for carrying out OCEAN activities has been completed and suitable systems have been set up at the sites where data processing and archiving will take place.

Work on the OCEAN software environment has been started with the definition of the new OCEAN format

### 1990 Milestones

| | |
|---|---|
| February | Meeting of the OCEAN Project Expert Group |
| March | Start of main OCEAN activities |
| May | First meeting of the ISY'92 PGO Expert Group |
| September | Conclusion of OCEAN level 1 development |
| September | Integration of hardware facilities complete |
| October | Start of CZCS level 1 data archival |
| December | Conclusion of OCEAN level 2 definition |

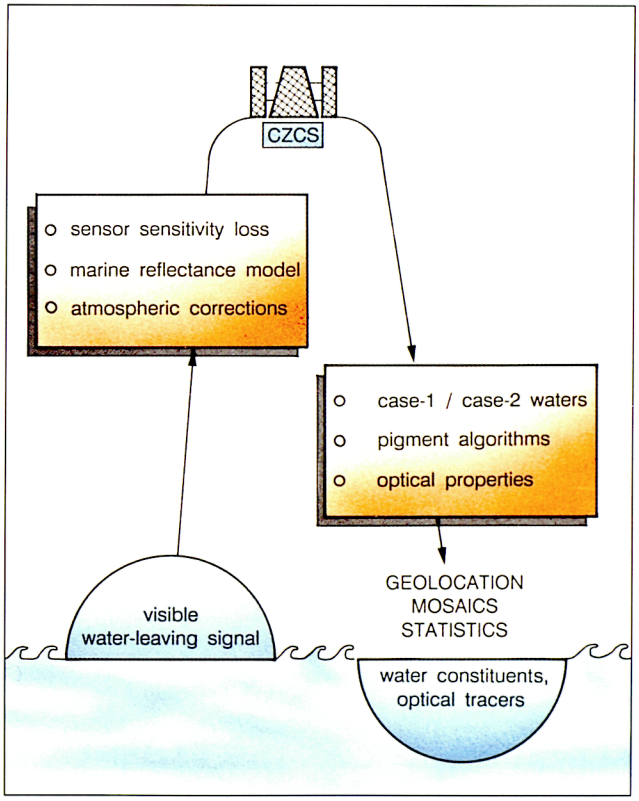


*Fig. 4.10: OCEAN algorithm set.*

for level 1 data (i.e. original CZCS image data integrated with geometric and atmospheric parameters). Further, level 1 software to generate the image data, and archive them with the new format, has been developed and implemented on the available hardware systems. In particular, IRSA contributed to the software package with a dedicated CZCS quick-look generating algorithm, which comprises a simplified (fast, but accurate) version of the correction algorithms to be used for level 2 data production.

The new OCEAN format for level 2 data (i.e. Rayleigh and ozone corrected radiances, water temperatures, pixel classification, including aerosol data based on Case-1/-2 water identification, and derived parameters such as plankton pigment concentration, total suspended matter, or other in-water optical parameters) has been defined. The establishment of level 2 software to derive marine environmental parameters from the image data has also been initiated. The software package will be a compilation of improved calibration, atmospheric and pigment algorithms for the derivation of value-added information from the historical CZCS data. The software will perform the suitable handling and processing of level 1 data, for the generation of the level 2 data base.

## The Application Demonstration Programme

Following the indications of the OCEAN Project Expert Group, a first core of application demonstration projects has been selected to provide requirements and guidelines for the mass production of CZCS value-added data. The regions (topics) covered by these existing project include:

- the north-eastern Atlantic Ocean (monitoring of long-term trends for JGOFS sites);
- the north-west Africa near-coastal area (study of upwelling phenomena and dynamics);
- the Mediterranean Sea (assessment of seasonality and basin scale variability; water quality in the Adriatic sea);
- the North Sea (evaluation of water quality in the German Bight and in the southern area);
- the English Channel (study of particulate transport);
- the Baltic Sea (study of surface bio-geochemical conditions).

In the processing/archiving phase, priority will be given to those data relevant for the demonstration projects (which are expected to start using OCEAN-supplied information in late 1991).

## ISY '92 Productivity of the Global Ocean

The OCEAN activities will constitute a substantial European contribution to the International Space year 1992 (ISY '92) initiative, through a programme titled "Productivity of the Global Ocean" (PGO) which is jointly led by IRSA and the Bedford Institute of Oceanography, Biological Oceanography Department of Dartmouth (NS), Canada. This programme has been proposed by the ISY panel of Experts on Earth Science and Technology, and approved for implementation by the Space Agency Forum of ISY (SAFISY). It is aimed at coordinating efforts towards the study of primary productivity in the sea, a key

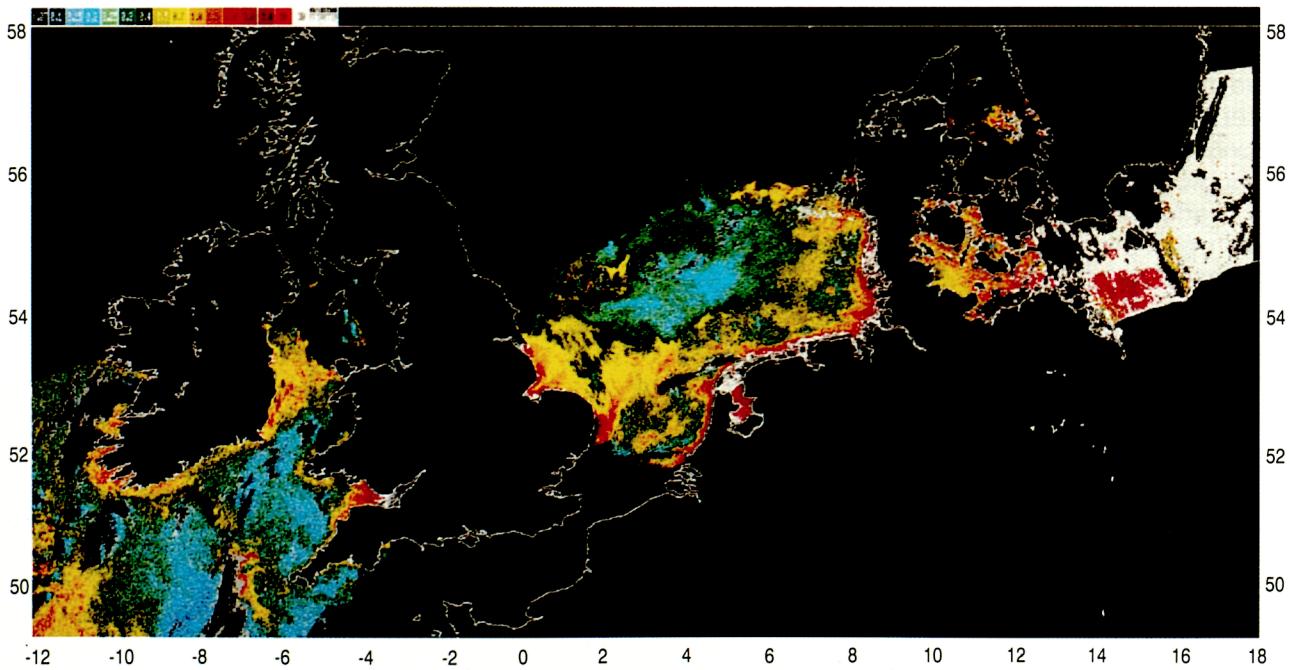


*Fig. 4.11: Chlorophyll-like pigment concentrations (29 July 1982) in northern european sea areas.*

parameter for the understanding of environmental mechanisms on our planet, but very difficult to quantify and still largely unknown.

Remote sensing of ocean colour is the major tool currently available for large scale, long term, synoptic assessments of marine (planktonic) primary producers. Hence the PGO project is concerned with (i) organizing catalogues and archives of CZCS data, the major source of ocean colour data up to the present; (ii) promoting the development and validation of algorithms for the retrieval of accurate sea surface chlorophyll concentration from such data, and encouraging their use in studies of marine productivity; (iii) preparing for a rational exploitation of the potentials offered by future ocean colour missions.

Progress on these topics has been made to ensure the coordination of ongoing activities (i.e. the OCEAN Project itself, the CZCS Global Data Set Project by NASA, and an analogous initiative now being undertaken in Japan); the publication of reference documents (e.g. the planned CZCS Archives and Algorithms Handbooks); and the organization of special workshops (e.g. the proposed "Ocean Colour: Theory and Applications in a Decade of CZCS Experience", to be held at JRC, Ispra, in the framework of the EUROCOURSES series).

## Perspectives for 1991

The short term development of OCEAN activities calls for the completion of level 1 data processing and archiving. After the implementation of the relevant software, the production of level 2 data will also start. In parallel, the definition, realization and implementation of level 3 software to produce geocoded time series, as well as composite and statistical images of environmental parameters, will be carried out. Such imagery will be supplied to the application demonstration projects as it becomes available. The preparation of an OCEAN Announcement of Opportunity shall also begin, together with the coordination of Project activities in the framework of the International Space Year 1992 initiatives.

In the longer term, it is expected that the production and dissemination of CZCS value-added data (level 2 and level 3), following the OCEAN Announcement of Opportunity, will contribute to the full exploitation of the scientific potential of ocean colour, in support of existing research activities as well as in preparation for future ocean colour missions.

# 5 MONITORING TROPICAL VEGETATION

*Contact:* J. P. Malingreau

## Staff

| | |
|---|---|
| Scientific and Technical Staff | 7 |
| Secretarial Support | 1 |
| Students | 3 |
| Visiting Scientists | 1 |
| Detached Experts | 0 |
| Total | 12 |

## Publications

| | |
|---|---|
| Journal Papers | 5 |
| Conference Papers | 13 |
| JRC Reports | 3 |
| Books/Chapters | 8 |
| Total | 29 |

## Facilities

- Compaq 386/33 with ERDAS and AVHRR pre processing software
- Tape drives
- Archive of GAC AVHRR data for Africa 1981-89 daily, for Asia 1986-89 daily

In order to respond to the needs of development policy within the CEC (Directorate General VIII) IRSA is using earth observation data in three application areas:

- Agricultural Production: These studies are undertaken in cooperation with the project "Monitoring of Renewable Resources In The Sahelian Countries", which is supported by the Comité Permanent Inter-Etats de la Lutte contre la Secheresse au Sahel (CILSS) and the European Development Fund (EDF).
  The research is concentrated upon the estimation and forecasting of rainfed crops. Low spatial resolution AVHRR and high spatial resolution SPOT and Landsat data are used in combination with ground measurements to prepare yield forecasts and estimates of cultivated areas.
  Four west African countries are presently covered by this research, namely Senegal, Mali, Burkino Faso and Niger.
- Hydro-Ecological Studies: Stratification of the upper Niger basin in Guinea is being undertaken using conventional morphometric measurements and satellite derived observations using Landsat Multi-Spectral Scanner (MSS) imagery. SPOT HRV imagery is being used to assess seasonal variations insurface water area. AVHRR data are used to provide inter-annual comparisons of vegetation dynamics.
- Tropical Deforestation: This is one of the most pressing environmental problems of the 20th century. AVHRR time series at both 1km and 4km spatial resolution are being used in the framework of a global tropical deforestation assessment.
  Fire is seen as an important agent of change in tropical biomes and the thermal channels on AVHRR are used to monitor fire events and burning patterns. Fires also have important implications in terms of atmosheric chemistry and global change. Deforestation and fire monitoring therefore form part of the Institute's activities within the International Geosphere - Biossphere Programme (IGBP).

# 5.1 FOREST MONITORING AND BIOMASS BURNING

***Summary of objectives***
*Development of techniques for the identification and monitoring of active deforestation fronts and areas of biomass burning using low resolution AVHRR satellite imagery*

## 1990 Programme of Work

### Introduction

Monitoring changes in the forests of the tropical belt represents a formidable challenge for remote sensing. Indeed, these changes are taking place over large areas and are sometimes accelerating in pace. A recent FAO evaluation indicates that the rates of deforestation in the 1981-90 period (168.000 $km^2$/year) may be nearly double that of the 1976-80 period (92.000 $km^2$ /year).

In line with these facts, and consistent with the overall objective of the project, research has concentrated upon the use of low resolution AVHRR data for assessing changes in the tropical forest canopy. This objective was seen as the first step in preparing a global forest inventory and monitoring exercise planned in the framework of the TREES Project, to be started in 1991 and 1992. With repeat to these objectives data sets have been examined over West Africa and Southeast Asia.

In addition the effects at fire as an important agent of change in tropical ecosystems have been included. It is also a major mechanism of interaction between the biosphere and the atmosphere. Biomass burning from savanna and tropical deforestation could account for 50% of the anthropogenic $CO_2$ released into the atmosphere. Controlling biomass burning is also at the core of improved land management practices in many countries of the tropical belt. Information on the timing and location of fires and their inter-annual variability is thus an important element in the study of tropical and subtropical ecosystems. Satellites have a significant contribution to make in this respect.

### Forest Monitoring

West Africa: In 1990 work concentrated on the analysis of the spatio-temporal variability in spectral signals and on the production of the final forest map derived from the application of the method to the major part of tropical West Africa.

**1990 Milestones**

- Creation of a final forest cover map for West Africa
- Creation of a preliminary forest cover map for S.E. Asia
- First steps towards the calibration of coarse scale AVHRR for active bush fire detection

In the large vegetation formations identified using the spectral evolution of temperature and vegetation index data, an additional element of ecosystem characterization was analyzed. At the 1km AVHRR scale, the evolution of the local coefficient of variability (on fixed windows) was found to be linked to the type of formation.

When applied to the whole West African subcontinent, the evolution of the local coefficient of variability clearly follows phenological events associated with the appearance of the dry season. This characteristic can be used as an additional element of classification especially when dealing with low resolution images in which textural details are of little support.

A final forest - non forest cover map for West Africa has been derived following the methodology tested over specific sites (see the 1989 Annual Report). The map was produced using a mosaic of dry season AVHRR 1km images processed using an unsupervised classification algorithm applied to four spectral channels. The output classes were reconsolidated by manual interpretation in the two resulting classes. Verification was carried out on transition areas only (Ghana and Guinea).

South East Asia: The perspective adopted in the analysis of AVHRR data over Southeast Asia was similar than that applied to West Africa; the objective was thus to test the feasibility of analyzing the low resolution multispectral data set for forested areas where both evergreen and seasonal formations are to be found. The analysis of three 1983 NOAA AVHRR orbits over continental southeast Asia has been completed.

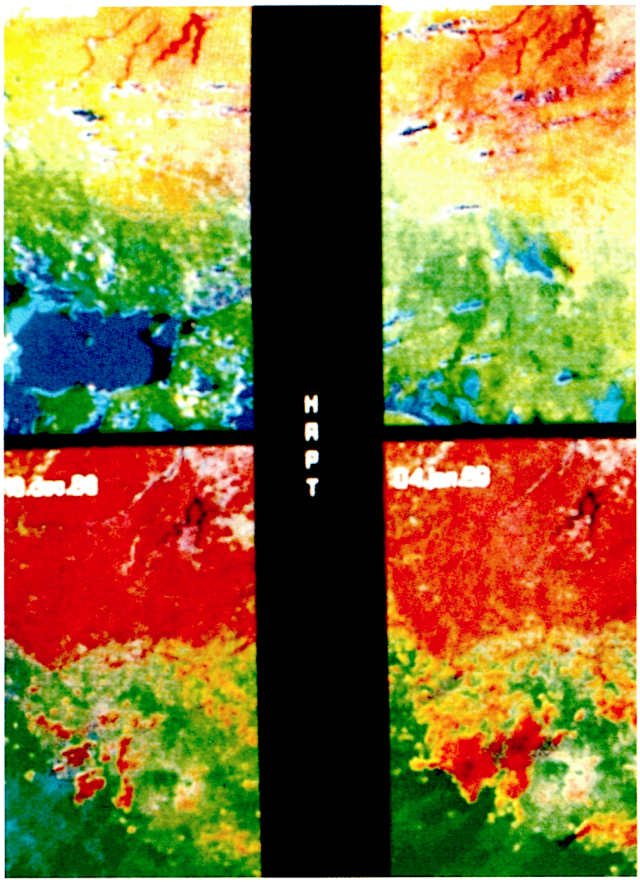


*Fig. 5.1: An example of the use of AVHRR images for bush fire monitoring. The image is of the border between Guinea and Liberia, West Africa.*

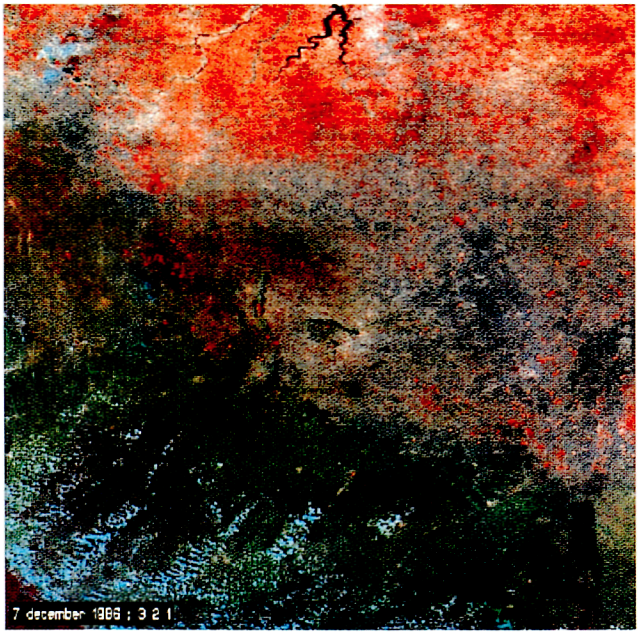


*Fig. 5.2: Use of AVHRR imagery for tropical forest mapping: an example from W. Africa (remaining forest blocks appear as very dark green).*

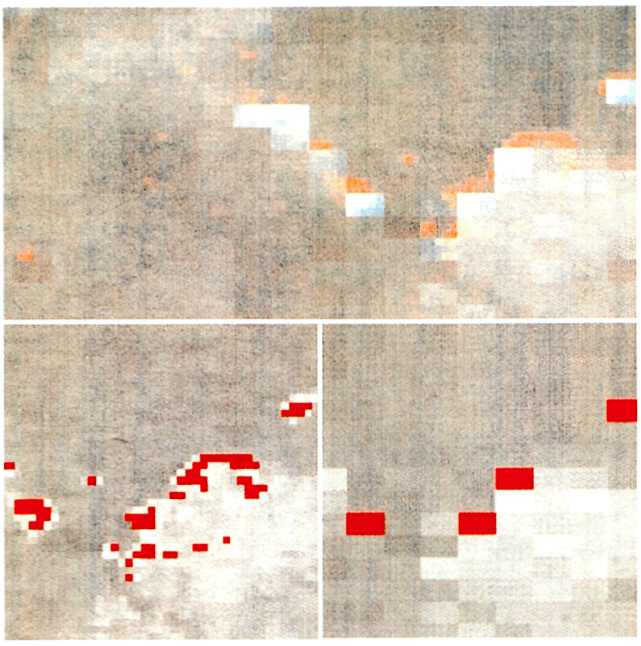

*Fig. 5.3 Fire detection using AVHRR at two different resolutions: HRPT 1 km resolution (bottom left) and GAC 4 km resolution (bottom right).*

The approach includes:

- Manual geometric correction of the three scenes using map reference points.
- Application of a cloud and sea mask using the visible, near infrared and thermal channels.
- The calculation of maximum NDVI and mean NDVI for the three available dates.
- An analysis of the NDVI evolution during the time period for selected forested area.
- Determination of the spectral characteristics of forest features in view of establishing threshold values for forest - non forest discrimination.
- An automatic unsupervised classification using the Mean channel 2, Mean channel 3, Mean NDVI and Maximum NDVI.

The resulting regional classification covers the following countries: Myanmar, Thailand, Cambodia, Laos and part of Vietnam.

The analysis has shown that the exploitation of AVHRR data sets must start with an exploratory phase characterizing features of interest. Classification approaches can only be efficiently adopted after this first step has been successfully completed. The conclusion is that while an overall methodological approach can be defined, its implementation must be locally adjusted.

## Biomass Burning

Work has concentrated on the analysis of fire patterns from two distinct but closely linked aspects of the

study. The first relates to an analysis of the impact of fire on the vegetation cover of selected watersheds using the AVHRR 1 km resolution (See also Section 5.3). The second line of study relates to the development of a "global fire product" using the AVHRR GAC 4 km resolution data, the only global satellite data available at this time.

Progress in this work can only proceed if the effect of the sampling applied to the original data set can ascertained. A "scale" study has been initiated in which the comparison between the 1 and the 4 km data has led to the following conclusions:

- The ability of the 4km data to detect active burning events is largely dependent on the shape and orientation of the fire fronts. In the west African savannah study area the fires tend to be narrow burning fronts (around 50 m or so) extending over a number of kilometres. If the fires have an approximate east-west orientation then they run roughly parallel to the AVHRR's scan lines; the particular characteristics of the 4km data mean that in this case fires can easily be missed. In contrast, fire fronts running north-south can usually be detected.
- The use of the 4km data for the precise estimation of the ground area burning needs to be quantified; because the fire events are actually smaller than the ground resolution of the AVHRR data used there is a risk of over-estimating the ground area burning for any fire detected.

A continuation of the scale study aims to establish the probabilities of exact fire detection and also to determine accurate area estimates using the 4 km product.

Work has proceeded with an examination of three years of dry season GAC data in order to assess inter-annual variability in fire patterns and burned areas and to derive improved specifications for the future processing of a "fire product"

### Perspectives for 1991

Future work in forest monitoring will concentrate upon:

- The characterization of the seasonality of the south-east Asian forest using GAC time series of data.
- The comparison with 1989-90 AVHRR 1km data for assessing changes.
- Further exploration of other data sets covering the tropical forests of Asia and, possibly, Central Africa. High resolution data (SPOT, Landsat TM) are to be used as a means of validation of the AVHRR analysis.

Future biomass burning research will concentrate upon:

- The continuation of the comparison between the 1 km and 4 km AVHRR data for fire detection over selected areas of West Africa; comparison with high resolution data (SPOT/Landsat).
- The definition of fire and burned area measurements which could summarize seasonal burning situations over large regions.
- The processing and analysis of multi-annual GAC data sets over the complete northern forest savannah transition belt for Africa.
- Joint analysis of the vegetation index information and fire patterns (fuel loading and burning patterns).
- Linking biogenic emission models and remote sensing derived information in order to better estimate the actual contribution of various ecosystems to changes in atmospheric chemistry.

# 5.2 MONITORING AGRICULTURAL PRODUCTION IN SAHELIAN COUNTRIES (In Support of DG VIII Development Aid)

***Summary of objectives***
*Development of remote sensing-based methods for acreage and yield estimation of rainfed cereals in Sahelian Countries.*

## 1990 Programme of Work

### Introduction

The general objective of this activity is to develop remote sensing-based methods for assessing rainfed foodcrop production in Sahelian Countries. This includes the derivation of acreage and yield estimates from satellite measurements combined with field observation at scales ranging from the administrative district to the sub-continent.

The contract between JRC and the interstate Committee for Drought Control in the Sahel (CILSS - Comité Inter-Etats pour la Lutte contre la Sécheresse au Sahel) came to an end in 1989. A redefinition of the partnership with this Institution, as well as with other potential partners involved in agriculture monitoring in West Africa, was undertaken. As a result a 3-year agreement for technical and scientific cooperation between the IRSA and CILSS was signed in January 1990. The IRSA activities carried out in this framework are part of the Support to the Commission and are covered by an agreement signed between JRC and DG VIII.

The redefinition of our cooperation with the CILSS was an opportunity to reorientate on-going activities by focussing the research effort on crop production monitoring at sub-continental levels.

The activities undertaken in 1990 include:

- A feasibility study of assessing harvestable acreage with high resolution imagery for sub-continental monitoring.
- A feasibility study of differential monitoring of agricultural areas with AVHRR HRPT data (1 km ground resolution at nadir) for the derivation of yield figures and crop phenological parameters with the aid of field observations.
- An inter-annual analysis of regional vegetation indices in relation with official yield statistics and agrometeorological information.
- An analysis of an integrated system for agricultural production monitoring.

**1990 Milestones**

- preliminary feasibility study of pre-harvest crop acreage assesment with high resolution satellite data.
- field and satellite data collection to empirically study the usefulness of vegetation indices for crop yield assessment and the establishment of actual crop calendars.
- inter-annual analysis of relationships between regional satellite vegetation indices and official crop yields from agricultural surveys.
- design of an integrated data management system for agricultural production monitoring.
- survey of European resources and R & D potential in fields related to agricultural production monitoring in Sahelian Countries.

- A survey of the European research capabilities in domains related to crop production monitoring in Sahelian Countries.

### Harvestable Acreage Estimations

A test-site which takes into account a wide range of potential environmental conditions, such as topography, cloudiness, and mixed cropping, was chosen in Burkina Faso. Images were acquired during the 1990 rainy season and pre-processing was started, including the computation of a digital elevation model with SPOT panchromatic data.

Preliminary conclusions indicate the need for significant improvement in the time lag between image acquisition and delivery to the customer for high resolution images received at the Maspalomas station.

The first image analysis suggests that cropped surfaces present a very low biomass amount, which will make it difficult to differentiate between harvestable surfaces and bare soils.

### Monitoring Using AVHRR HRPT Data

The CILSS - EDF project "Monitoring of Renewable Natural Resources in the Sahel" organized the field

data collection on about 25 test sites in the Western part of Niger. This includes bi-weekly observations of crop development and measurement of biomass variables at harvest time.

In addition a PC-based AVHRR-HRPT data processing chain was made operational. The current system allows radiometric and geometric correction of about 8 HRPT images in standard ESA/SHARP format per working day. The data set derived from the Maspalomas station will include daily AVHRR images (NDVI, surface temperature, albedo and an estimate of the precipitable water content of the atmospheric column) covering the entire rainy season, as well as derived products such as 10-day maximum NDVI value composites, land-use maps derived from Landsat MSS images, administrative boundaries and field data.

The analysis will focus on an empirical calibration of the vegetation index with yield and phenological parameters observed on the 25 test-sites and on the relation between satellite spatial resolution and the size of the agricultural areas. These results will lead to an assessment of the usefulness of HRPT data for rainfed crop monitoring in West African conditions.

As a preliminary step a first set of 160 HRPT images, from mid 1987 to early 1990, covering southern Mali have been processed. Results show that NDVI, surface temperature and albedo temporal development can clearly be linked to growing period. However, the data suffer from detrimental atmospheric effects. Although cloud masking and NDVI maximization remove optically thick clouds, haze and aerosol related contamination remains. These pose considerable problems for the spatial analysis of the data sets.

Other limitations identified include the frequent saturation of the AVHRR thermal sensor which severely affects the analysis of the surface temperature data. Future data pre-processing will aim to deal with some of the atmospheric contamination problems identified; the estimate of the precipitable water content of the atmospheric column would appear to be a valuable source of information for improving data correction.

### Inter-Annual Analysis of Regional Vegetation Indicies

Preliminary studies have shown that vegetation indices derived from AVHRR data and averaged over administrative districts can be used to describe crop yields at the sub-continental scale.

The inter-annual comparison confirmed this view. The seasonal evolution of the relationship between time-integrated vegetation indices and the final crop yield can be modelled and thus predicted. Poor quality satellite data and inaccurate crop yield statistics do not allow the calibration of the remote sensing data used for this experiment.

### An Integrated System for Agricultural Production Monitoring

The aim of this exercise is to design and build a system which integrates all the steps in the data flow, including data acquisition, pre-processing and processing, analysis, storage of the resulting information in an on-line data base, and interface between data base and end-user. The design will be ready by early 1991.

### European Research Capabilities in Sahelian Crop Production Monitoring

A survey has been commissioned to identify European laboratories and institutions actively engaged in research concerning crop production monitoring in Sahelian Countries. The survey also includes non-European institutions, though is less comprehensive in this respect.

The results are to be published as a directory, available early in 1991. This directory will complement those recently published by other organizations as it covers both remote sensing and non-remote sensing based groups.

### Perspectives for 1991

Work in 1991 will concentrate on three major activities:

- With respect to an assessment of harvestable acreage using high resolution satellite data, an extensive campaign is being organized over the Burkina Faso test-site. This will include ground data collection, air photography campaigns, SPOT and TM satellite imagery. Several contacts in Africa as well as in Europe will be involved in building this data set and in processing and analysis of the data.
- Processing and analysis of the 1990 and 91 AVHRR HRPT data set will be carried out using ground observations provided by the CILSS "Monitoring" project.
- The development of crop status monitoring methods at the sub-continental level through the systematic analysis of AVHRR archive data will be undertaken.

It is hoped that the first two studies above will be finalized by mid 1992 and will provide ways of using remote sensing data in an operational manner for assessing harvestable crop acreage and yields.

# 5.3 MONITORING ENVIRONMENTAL CONDITIONS OF LARGE WATERSHEDS (In Support of DG VIII Development Aid)

***Summary of objectives***

- *Quantitative evaluation of hydrological consequences of changes in vegetation cover of large river basins in Africa.*
- *Use of low resolution AVHRR imagery and hydrological models.*

## 1990 Programme of Work

### Introduction

Among the natural resources supporting human needs and economic development, water is obviously of special importance, both in terms of quantity and quality. This is particularly true in the developing countries of the tropical belt where limited amounts of rainfall in most of the areas between the tropics, population growth and migrations, and limited financial resources all contribute to a growing need for effective water resource management at all levels.

Only part of the precipitation received by an area will contribute to the water reserves in the environment (in the soil, the vegetation cover, the deep ground water tables and the surface water bodies). This partition is driven, to a large extent, by the surface characteristics of the environment among which the vegetation cover status is by far the most important factor controlling the contribution of rainfall to the water reserves. Any changes affecting the vegetation cover, due to natural or anthropomorphic reasons, will have direct consequences on the water resources. It is in this context that research activities are conducted for the monitoring of environmental conditions of river basins important for water resources.

In 1990 work has concentrated on monitoring seasonal or inter-annual changes in land surface characteristics of large rivebasins relies on time series of NOAA-AVHRR HRPT data and on the building of a data base containing biophysical parameters related to the "quality" of the surface. After processing the imagery, four parameters are currently derived from the AVHRR time series: the surface temperature from channels 4 and 5, the NDVI from the visible bands, the averaged value for a given watershed in the middle infrared (channel 3) and a fire intensity index (FI) again derived from channel 3.

An established database containing watersheds boundaries for 21 rivers of West Africa (see the 1989 Annual Report) provides polygon files usable as graphic overlays on the AVHRR time series. Combining the image and graphic databases allows the creation of a biophysical database for the monitoring of watershed surface characteristics.

The 1989 work related to the monitoring of selected river basins in the sahelian (Faleme) and soudanese

### 1990 Milestones

- Extension of the geographical area in order to include a third ecological domain of West Africa: the guinean, centred on the Sassandra river basin
- Extension of the AVHRR-HRPT time series in order to cover the 1988 /1989 hydrological year
- Testing of existing hydrological models compatible with the use of AVHRR derived parameters

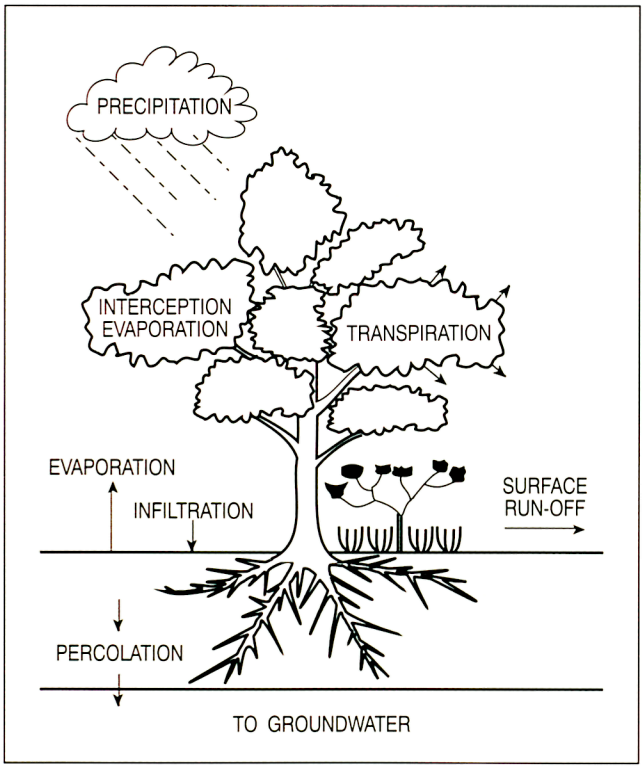


*Fig. 5.4: Water processes at the surface, in the presence of vegetation (adapted from Verstraete and Dickinson, 1986).*

(Niger tributaries) domains of West Africa for the 1987/1988 period has, in 1990, been extended along four main lines:

- The image and biophysical databases have been updated to include the 1988/89 period.
- The methodology has been applied to two more important ecological domains, namely the guinean, centred on the Sassandra tributaries at the border between Guinea and Ivory Coast, and the transition zone located between the soudanese and guinean domains in the southern part of Guinea.
- The selection and testing of criteria for the quantitative study of bush fire activity within the watersheds has seen the development of a fire intensity index.
- The feasibility of using data derived from the AVHRR time series as input parameters for hydrological modelling has been examined.

## Application of the Methodology to other Ecological Domains

Results previously obtained in the sahelian and soudanese zones (Faleme and Niandan respectively) have been compared with the 1990 analysis in the guinean zone (Sassandra's tributary rivers, Nzo, Feredougouba and Bogho). Results demonstrate how the surface temperature and vegetation status as indicated by the NDVI vary both with time and location.

## The Quantitative Approach to Bush Fire Monitoring

The FI is derived from a combination of the total number of fire events observed during a given dry season and the percentage of these fire events observed at the end of the same period. This balances the number of fire events against their temporal pattern.

Such information is indispensable for impact studies as the consequences of bush fires in the environment are largely dependent on the period of occurrence; fires occurring late in the dry season have a greater detrimental effect on the environment than the early fires. Fig. 5.5 shows how the FI veries as a function of location, for example the low FI value for the northern Faleme watershed indicates that in this area late fires are comparatively rare. However, the precise definition of a "late fire" remains to be established. On-going research suggests that a possible answer could be given by considering the timing of the fires with respect to the temporal pattern of the mean NDVI value for the watersheds.

## Hydrological Modelling

A collaborative programme has been set up with the ORSTOM research institute (Department of Continental Waters) in Montpellier (France). The analysis of hydro-meteorological data from ground measurements in combination with surface characteristics as determined from the AVHRR time series for the

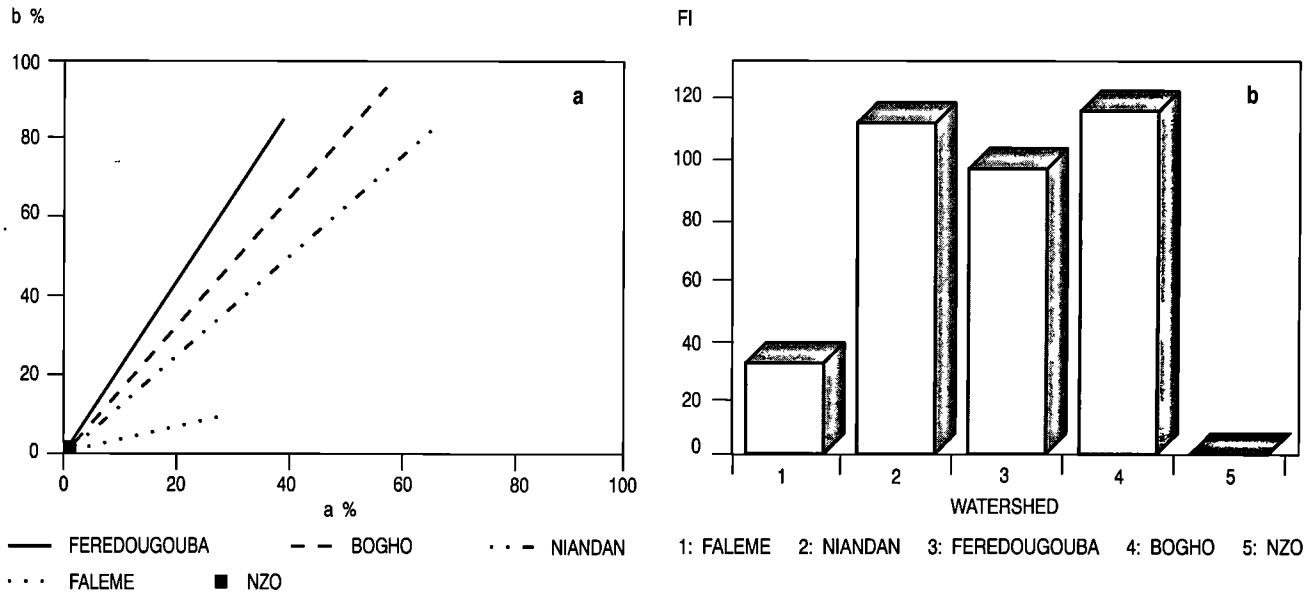


*Fig. 5.5: Evaluation of bush fire intensity on the watersheds:*
*a = cumulative percentage of watershed area affected by fire events during the dry season.*
*b = percentage of fire events observed in the second half of the dry season*

$FI = \sqrt{(a^2 + b^2)}$

1987/88 and 1988/89 periods shows, firstly the quality of the rainy season, in terms of quantity and spatio-temporal distribution within a watershed, can be characterized by the dynamics of the biophysical parameters as derived from the AVHRR-HRPT data; and secondly that such parameters could provide the information needed for the modelling of rainfall-flood relationships on large river basins (>10.000 $km^2$).

Current research is oriented towards a more systematic and quantitative parameterization of the surface characteristics, and a test of existing hydrological models using input data derived from AVHRR time series.

## Perspectives for 1991

Future work is focussed on the consolidation of the biophysical database built on AVHRR-HRPT data as they are produced by the Maspalomas receiving station on West Africa, and the adaptation of the methodology to the AVHRR-GAC imagery, as this product is a more extensive data set allowing:

- the study of hydrological changes over a significant time period (≥ 10 years);
- the extension of the geographical area of interest to cover river basins situated in Central and Eastern Africa.

# 6 ADVANCED TECHNIQUES

*Contact:* A. J. Sieber

## Staff

| | |
|---|---|
| Scientific and Technical Staff | 20 |
| Secretarial Support | 2 |
| Students | 2 |
| Visiting Scientists | 1 |
| Detached Experts | 0 |
| Total | 25 |

## Publications

| | |
|---|---|
| Journal Papers | 6 |
| Conference Papers | 30 |
| JRC Reports | 10 |
| Books / Chapters | 2 |
| Total | 48 |

## Facilities

Data processing facility based on SUN, incorporating in-house software for microwave data analysis
Software tools including relational data bases and GIS
Interim Signature Laboratory
European Signature Laboratory (in construction)
Plant physiology laboratory
Radiometry laboratory
Fluoroscence laboratory

Besides the development of applications of proven space borne sensors in the visible and infra-red range there is a need for the evaluation and promotion of more advanced remote sensing techniques, involving basic, systematic and long-term research. In order to address this requirement an Advanced Techniques Unit has been established within the Institute that is involved in the following activities:

- Microwave Remote Sensing: Spaceborne microwave systems will play an important role in remote sensing in the immediate future, as is clear from the announcement of the ERS-1, ERS-2, JERS-1 and Radarsat systems, and the Shuttle based systems SIR-C and X-SAR.These systems are a first important step towards the introduction of microwave remote sensing to a larger user community throughout the next decade.
  Currently, however, there is neither the technology nor the fundamental knowledge of the information content of the backscattered signal to either fulfill the requirements of the user community or to specify the requirements for advanced microwave systems in the future.
  IRSA has begun to fill this gap via the promotion of a coordinated research programme within Europe. This programme is based upon the following elements:
  - the implementation of a microwave signature laboratory which will be used for in-house research and which will be open for use to researchers, primarily from CEC member states;
  - the implementation of a European Airborne Remote Sensing Capability (EARSEC), to be undertaken in collaboration with ESA;
  - the promotion of application orientated airborne experiments in collaboration with ESA and national institutions;
  - the development of a standard data base for characteristic target parameters and calibrated radar signatures;
  - the development of application orientated radar data interpretation algorithms;
  - the promotion of application based pilot projects;
  - the dissemination of microwave related knowledge to the user community.
- Imaging Spectrometry: This technique is seen as extremely important for the future development of earth observation. The technique splits visible and infra-red light into high spectral resolution channels, the choise and the number of which depends upon the application requirements.
  IRSA have initiated a programme of activities to develop techniques for the handling and analysis of imaging spectrometer data, and the acquisition of these data via campaigns with airborne sensors, often undertaken in collaboration with ESA.
- Time Resoved Laser Fluorosensor: Several years ago the JRC embarked on the development of an advanced airborne sensor to analyse the spectral and temporal response of remote targets excited by laser light. The current application considered is the characterisation and possibly the thickness of oil spills on the sea surface.
  In addition it is also intended to examine other potential applications such as the measurement of water quality parameters, including chlorophyll, yellow substance and various chemicals.
- EUREKA Project LASFLEUR: The goal of this project, in which IRSA is participating, is to develop a system using laser spectroscopy to collect information on the state of plant health across large areas of vegetation. In essence the technique measures the physiological state of the plant.

# 6.1 MICROWAVE REMOTE SENSING

***Summary of objectives***

- *Development of applications of radar remote sensing techniques.*
- *Development and validation of methodologies for the practical use of data from space and airborne sensors for both operational applications and scientific investigations over land and sea.*
- *Stimulation of the effective use of radar remote sensing data resulting from on-going space missions.*
- *Identification of the needs and specifications of future missions based on principle application areas.*

## 1990 Programme of Work

### Introduction

The 1990 Programme of work concentrated on a number of aspects:

- Implementation of the European Signature Laboratory.
- Research in the field of radar imaging techniques and radar signature investigation using the Interim Signature Laboratory.
- Management of the airborne polarimetric campaign MAESTRO 1 and preliminary data analysis.
- Preparation for the ERS-1 projects in forestry (IFI and TREES) and agriculture (AGRISAR).
- Preparation for the European Airborne Remote Sensing Capability (EARSEC).

The work undertaken in each of these is summarised below.

**1990 Milestones**

| | |
|---|---|
| January | Interim Signature Laboratory became operational. |
| March | Critical design review of the European microwave signature laboratory. |
| May | MAESTRO 1 data received at Ispra |
| July | MAESTRO 1 Polarimetry Workshop (JRC Ispra) and MAESTRO 1 Data Workshop (JRC Ispra). |
| November | EARSEC Call for Proposals |
| November | MAESTRO 1 Data Quality Workshop (ESA, Frascati). |
| December | First components for the European microwave signature laboratory shipped to Ispra. |

### Implementation of the European Signature Laboratory

IRSA is installing an unique signature laboratory of dimensions 15m * 20m containing both microwave and optical sensors. The microwave sensors will be capable of measuring polarimetric monostatic and bi-static signatures over a frequency range of 1-40 GHz.

In November 1989 IRSA signed a contract with the German company Siemens to undertake the detailed design, development and installation of this laboratory.

In March 1990 the critical design review was held and successfully completed. Siemans then entered the manufacturing phase. By the end of 1990 the first components of the laboratory had been shipped to the JRC.

In parallel preparatory work was undertaken in the hall that will host the laboratory.

### Signature Research in the Interim Signature Laboratory

The Interim Signature Laboratory has been operational since the beginning of 1990, and has been continually upgraded since then.

The principle effort in the laboratory has been to establish different calibration procedures for polarimetric and single polarisation backscatter measurements, and to test components, software and signal analysis procedures in preparation for the full European Signature Laboratory.

In addition the Interim Laboratory has been used for radar signature experiments of natural and artificial targets. One of the main objectives of this was to investigate the sensitivity of radar backscatter at

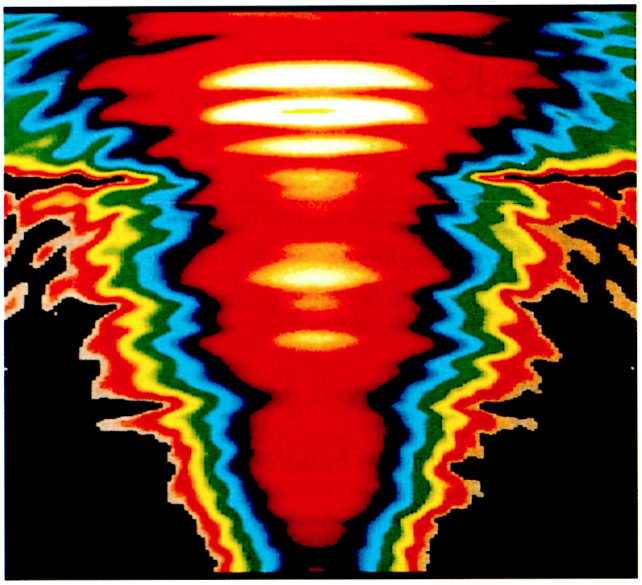

*Fig. 6.1: Azimuth antenna pattern as a function of frequency: result obtained from the interim signature laboratory.*

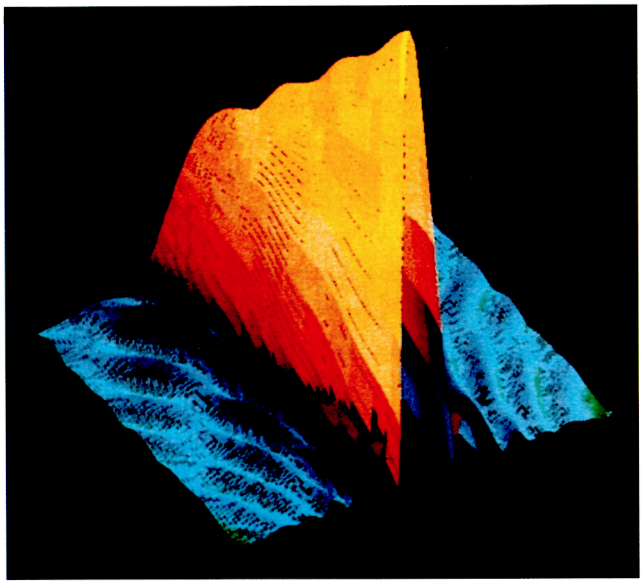

*Fig. 6.2: RCS of a metal plate as a function of aspect angle and frequency: result obtained from the interim microwave signature laboratory.*

different frequencies and polarisations to water stress in wheat and corn plants. In addition measurements were also taken of complex dielectric targets designed to model a small tree.

## Airborne Polarimetric Campaign MAESTRO 1

The MAESTRO 1 Campaign, a joint Campaign with ESA, was flown in 1989 using the DC8 aircraft and AIRSAR sensor of NASA and the JPL.

In 1990 the Campaign progressed into the data distribution and data analysis phases. The SAR data for the four Test Sites (Flevoland (NL), Freiburg (D), Landes (F) and Thetford (UK)) were processed at JPL and received at the JRC in May. These data were given a preliminary quality check at IRSA and then forwarded onto ESA and the Campaign's Principle Investigators (PI's).

Ground data as supplied by Coordinating Investigators (CI's) were also received at IRSA and then forwarded onto ESA and the Campaign's PI's.

In the frame of this Campaign the European Radar Cross Section data base (EURACS) was extended to incorporate ground data derived from forest areas. This included the definition of standard ground data collection protocols for forest experiments.

The data analysis phase was initiated via a series of Workshops organised by IRSA and ESA.

For the analysis of the polarimetric data specific software tools have been developed at IRSA. These include POLTOOL (a tool for the analysis of compressed Stokes matrix data), SMTOOL (a tool for the analysis of full scattering matrix data) and CALTOOL (a tool to calibrate radar data). POLTOOL has been distributed to over 30 institutes.

## Preparation of ERS-1 Projects

IRSA has three ERS-1 projects accpted by ESA:

- International Forest Investigation (IFI);
- AGRISAR - agricultural statistics in Europe;
- Tropical Ecosystem Environment Monitoring by Satellites (TREES) (joint project with ESA).

Major emphasis has been given to the preparation of a data base of ancillary information concerning the different Test Sites for the three projects.

In parallel the radar signal processing facility has been upgraded in terms of hardware and software. Software tools for the analysis of ERS-1 SAR data were developed, as well as procedures to handle the data.

## European Airborne Remote Sensing Capability (EARSEC)

During 1990 considerable emphasis has been given to the definition of objectives of the EARSEC programme.

In addition the JRC succeeded in obtaining funding from the European Parliament to establish such a European airborne platform of remote sensing sensors.

On this basis a Call For Proposals was distributed for airborne measurements in 1991. In this the sensor requirements, Test Sites and data acquisition requirements were specified.

### Perspectives for 1991

The objectives for 1991 are as follows:

- Handing over of the European Signature Laboratory to IRSA.
- Complete the data analysis for MAESTRO 1.
- Undertake the MAESTRO 1 Final Workshop and a Special Session on MAESTRO 1 at IGARSS'91.
- Undertake first analyses of ERS-1 SAR data.
- Fly the first EARSEC Campaign.
- Participate in the NASA AVIRIS and AIRSAR Campaign over Europe (MAC-EUROPE).

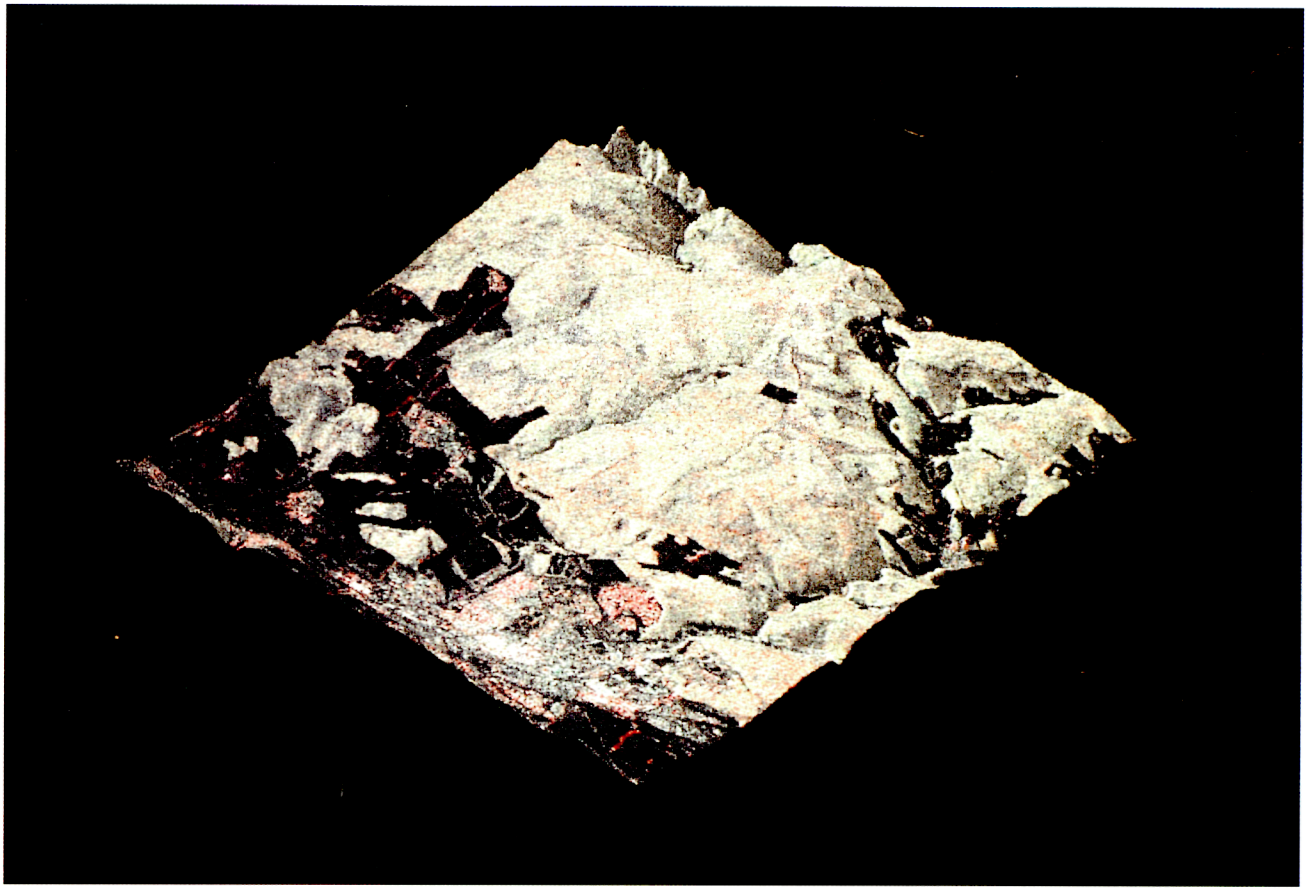

*Fig. 6.3: Geocoding airborne polarimetric SAR data for object classification: MAESTRO 1 data of the Freiburg (D) test site.*

# 6.2 FIELD RADIOMETRY

***Summary of objectives***

- *To set-up laboratory calibration techniques for field spectro-radiometers in the VIS and NIR range.*
- *To organize and perform radiometric ground truth campaigns for the validation of airborne and spaceborne sensors. Campaigns include both spectral signature measurements and ground based measurements of atmospheric parameters.*
- *Spectral feature identification for different applications, such as agriculture, oceanography and geology in preparation for future spaceborne sensors with high spectral resolution.*

## 1990 Programme of Work

### Introduction

In 1990 this activity concentrated on the following:

- the analysis of radiometric ground truth derived from the EISAC campaign
- specific measurement campaigns both in the laboratory and in the field for the understanding of ambiguous signatures
- measurements performed under controlled conditions for the identification of induced effects such as the water stress of plants
- comparison of ground based measurements and remotely sensed data for calibration and validation purposes.

The main results and some examples of the analysed data are summarized below.

**1990 Milestones**

| | |
|---|---|
| February | EISAC meeting on airborne data calibration and atmospheric correction |
| June | Contacts with University of Trier (Germany) and University of Utrech (The Netherlands) for the use of high spectral resolution images for the observation of Mediterranian land degradation and soil erosion (Ardeche test site) |
| September | Delivery to Ispra of the GERIS Mark IV single FOV spectro-radiometer for VIS, NIR and SWIR |
| October | Comparison of active and passive optical techniques for the detection of the water stress (LASFLEUR campaign) |

### Laboratory measurements

The different European laboratories involved in field radiometric activities were convened by IRSA with their instrumentation at the DLR laboratory, Oberpfaffenhofen (Germany). The analysis of the intercalibration measurements which had been performed were satisfactory and no significant differences in reflectance values, measured with different spectro-radiometers, were found.

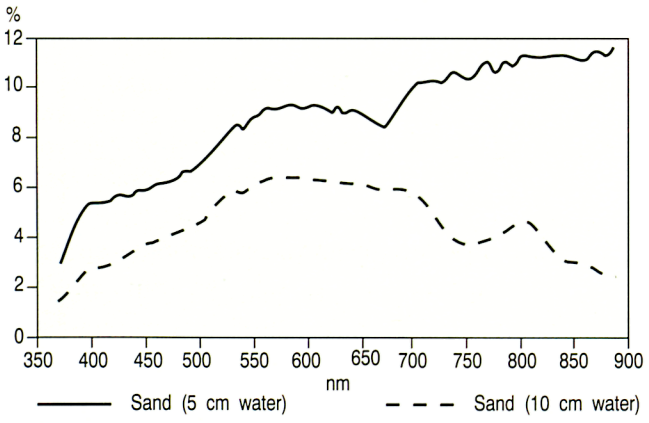


*Fig. 6.4: Absolute reflectance of sand under water.*

Furthermore it was possible to refer the different calibration panels of the various teams to the same standard. These values were then taken as an absolute reflectance. This approach was shown to be very useful for the unambiguous analysis of airborne data as well as ground measurements performed by different teams with different instruments and equipment.

### Field Measurements in the North Adriatic Sea

The test site used for the radiometric measurements was the Sacca di Goro in the Po delta. The measurements were carried out in collaboration with the Assessorato Ambiente of the Amministrazione Provinciale di Ferrara on board the research vessel HYDRA. A correlation between the measured chlorophyll (Chl) content and the surface area of the Chl fluorescence

peak, visible in the reflectance spectra around 685 nm, has been made yielding some promising results.

Although a definite trend can be observed in the reflectance spectra, the correlation obtained is not sufficient for a precise quantification of the chlorophyll content. For instance, in such a test site, the sea bed is often visible and is furthermore quite variable. This can have a significant influence on the characteristics of the surface reflectance data and can be misleading when only the correlation with the water properties is concerned. In order to experimentally investigate the wavelength dependence of this effect and to provide data for modelling, the spectral reflectance of sand at the water's edge has been measured and the effect of varying depths of sea water on a uniform bed of sand was determined.

The properties of the water body can also vary considerably within a very small area and the water sample used for the measurement of discrete parameters may not correspond exactly with that covered by the radiometric measurement. Therefore, several measurements have to be taken around the same point in order to increase their statistical validity and to have a representative datum to be compared with the spaceborne data which generally averages over a larger area than that seen in the field of view of the instrument. Due to this further investigation and measurements, both in field and in controlled conditions, have been carried on during 1990. They will have to be implemented in a modelling activiity for such a complex natural system.

## Field Measurements in the Upper Rhine Valley

Radiometric measurements were also carried out in the Upper Rhine Valley. The measurements were concentrated in an agricultural zone south of Colmar (France) and a hilly area north of Colmar (France) containing vineyards and woodlands. They have been used, when possible, for comparison with the airborne data.

The ground measurements, carried out at Freiburg, were used for the adjustment of the radiometric calibration of the airborne imaging spectrometers. Here, a number of grey panels were put together to form a large reference panel (200 m.sq.) visible in the airborne data of June 13th. The absolute reflectance of this assembly was measured both with the Spectron SE590 (JRC) and the IRIS (DLR) spectro-radiometers.

By means of data collected with the two spectro-radiometers previously calibrated at the DLR, it was possible to derive an inflight calibration of the GER-64 which had an incorrect preflight calibration. According to this positive experience another radiometric field measurement campaign was carried out during a test flight with the CASI airborne image spectrometer which was performed in July 1990 at the Freiburg (Germany) test site.

*Fig. 6.5a: Maize field near Colmar (F) where reference measurements have been performed.*

*Fig. 6.5b: Radiometers and spectro-radiometers in the field for measurements of both spectral signatures and atmospheric parameters.*

## Atmospheric Measurements

At both test sites, measurements of the atmospheric beam transmittance were performed using a band-pass radiometer (EXOTECH) and a spectro-radiometer (SE590). The method used is that of Langley. A satisfactory agreement has been obtained between the two types of instrument although further measurements of this kind under stable atmospheric conditions are required in order to establish a fast and

reliable procedure for the measurement of atmospheric beam transmittance in a continuous spectrum. In the case of the SE590 measurements, a best fit of direct irradiance values and air mass has been established for the 252 channels of the spectroradiometer. This kind of data is directly applicable to the airborne data obtained during the FLI/GER overflights over the two test sites concerned and thus atmospheric corrections can be performed in order to have a better correlation between ground and airborne data.

### Perspective for 1991

The objectives for the 1991 are as follows:

- To develop a proper methodology for measurements in field with the GERIS Mark IV spectroradiometer.
- To participate in the AVIRIS part of the MAC-EUROPE campaign.
- To participate in the land degradation/soil erosion activity with field and laboratory measurements.
- To continue laboratory measurements for the comparison of different remote sensing techniques such as reflectance analysis (passive) and excited fluorescence (active).
- To contribute to the first EARSEC campaign.

# 6.3 LIDAR FLUOROSENSING

***Summary of objectives***

*Development of a time-resolved lidar to monitor the marine environment for the purpose of:*

- *identification of the type of oil present in a slick on the sea surface*
- *characterization of the sea water, including the optical attenuation coefficient, evaluation of suspended matter, dissolved organic matter and phytoplankton*

## 1990 Programme of Work

### Introduction

The initial objective of this activity is to develop a lidar capable of identifying the type of crude oil present in a slick on the sea surface. A laboratory study of oil's fluorescence characteristics led to the concept of a high temporal resolution (1 ns) instrument using techniques never before implemented in a lidar, in particular a mode locked Nd-YAG laser and a streak camera as the detector. The construction of the TRLF was contracted to CISE S.p.A. of Italy in 1986. In parallel, the laboratory was re-equiped to support the lidar data analysis on the basis of well controlled simulation experiments.

The application of high temporal resolution to the characterization of the water column was later studied. The key point here is that the technique potentially allows the accurate measurement of the water beam attenuation coefficient.

**1990 Milestones**

| | |
|---|---|
| February | technical reception of the flight instrument ("Time Resolved Lidar Fluorosensor", TRLF) |
| March | ground test of the TRLF both on oils and water column targets |
| May | calibration of the support laboratory streak camera |
| May | installation and calibration of a second, highly sensitive streak camera |
| June | TRLF exhibited at "Europa Ricerca", Rome |
| September | senes of reference measurements on crude oils and other oil products - new approach for the fingerprinting criterion |
| November | TRLF exhibited at "VI Salone Internazionale delle Nuove Tecnologie e dell'Innovazione, Torino |
| November | TRLF presented to the 18th ACPH committee |
| November | series of measurements on the artificial water column with various concentratioins of DOM and analysis on the basis of a physical model |

### The Airborne "Time Resolved Lidar Fluorosensor" (TRLF)

The instrument was delivered to Ispra at the end of February. The reception tests have been conducted in collaboration with a team from CISE. The delicate alignment operations were performed on this occasion. Some minor modifications to the instrument were undertaken at this time, including the substitution of the collecting optical fiber, software correction of the fiber chromatic dispersion, and the introduction of spectral filters.

The measurements performed for the technical reception have provided the material to produce a brochure describing the instrument and its possibilities for oil detection and water column studies. The instrument was then put on display at two scientific exhibitions; it has also been presented to national experts in sea pollution during the 18th meeting of the ACPH committee (CEC, DG XI) and to several oil companies (in view of its possible use for oil prospecting).

The instrument has raised the interest of an aeronautical firm (Agusta) resulting in a Third Party Work contract aimed at testing the TRLF on an helicopter in view of designing an industrialized version of the instrument.

In addition the initial objective of testing the TRLF on a G222 airplane of the Italian "Protezione Civile" has been pursued. The detailed projects of the mounting interface platform has been evaluated and modifications to the instrument in order to comply with the safety regulations have been undertaken.

### Laboratory Studies on the Fluorescence of Oils

A new series of reference measurements on 12 crude oils have been performed. The full spectro-temporal

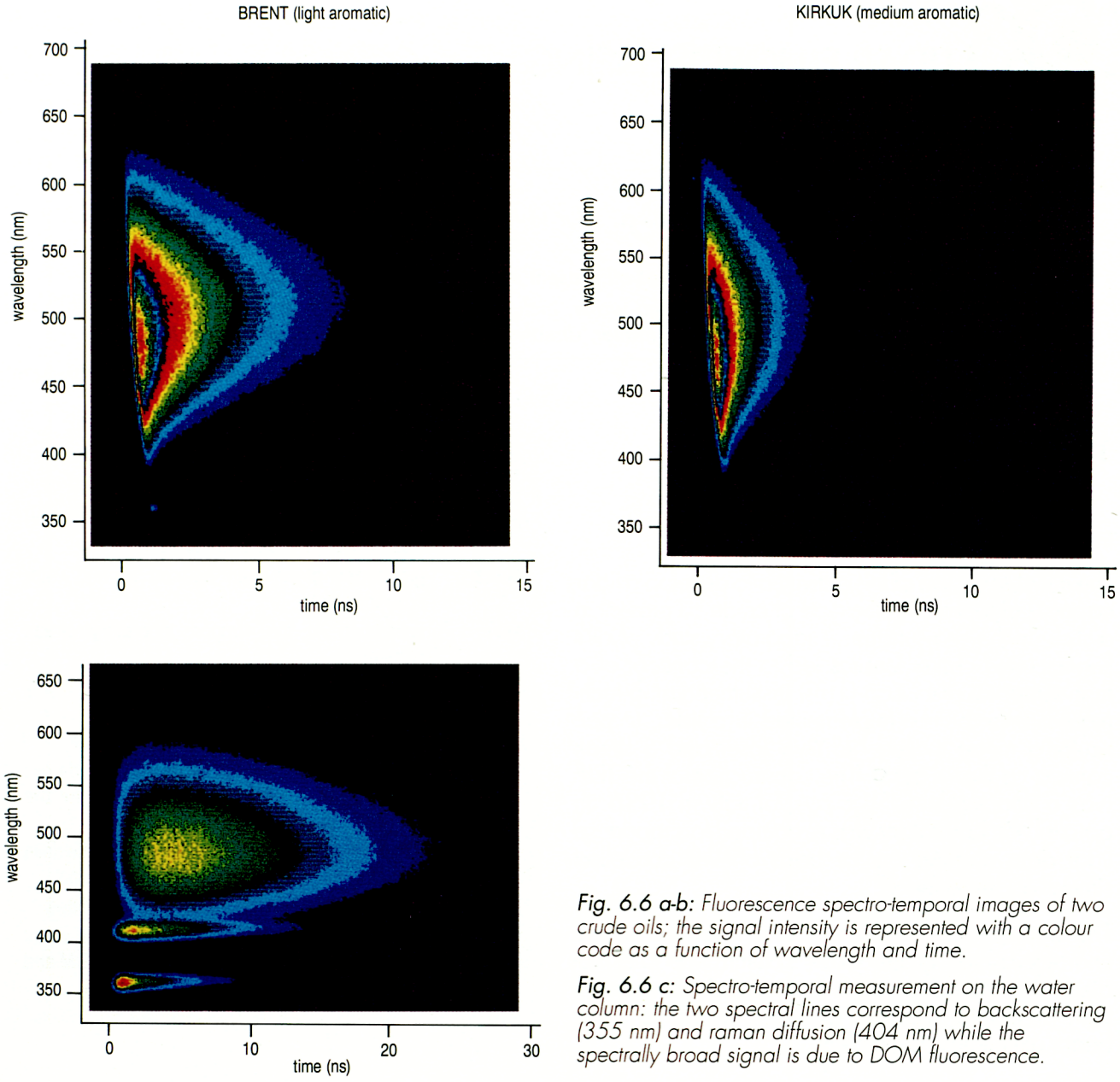


*Fig. 6.6 a-b: Fluorescence spectro-temporal images of two crude oils; the signal intensity is represented with a colour code as a function of wavelength and time.*

*Fig. 6.6 c: Spectro-temporal measurement on the water column: the two spectral lines correspond to backscattering (355 nm) and raman diffusion (404 nm) while the spectrally broad signal is due to DOM fluorescence.*

response of these oils was recorded and analysed. The temporal decay was found to be more complex than the previous, less accurate, measurements had indicated. The temporal response cannot be described by a single decay time; instead a minimum of three exponential components is needed to fit the experimental response.

Though of interest, this detailed analysis is not well adapted to the purpose of a rapid identification of the product, therefore a revised fingerprinting criterion based on the emission spectrum and the temporal barycenter of the signal (as a function of wavelength) has been defined. This parameter is rapidly computed, is sufficiently discriminative and is much less sensitive to the experimental uncertainties than the exponential decay times.

These measurements were also extended to other oil products such as fuels oils, diesel combustible oils and petrol.

## Laboratory Studies on Natural Water Characterization

Several spectro-temporal measurements have been performed by using the artificial water column facility with the purpose of testing the models which describe the temporal dependence of the various signals (backscattering, water Raman diffusion and DOM fluorescence). A particular experiment was conducted by initially filling the tank with tap water and then adding known quantities of humic acid to simulate an increasing concentration of DOM and thereby diminish the optical transparency.

The analysis has been undertaken and the first results are promising regarding the possibility of accurately measuring the water beam attenuation coefficient from the backscattering and Raman signals while the model describing the fluorescence signal has to be further improved.

A prospective study on the possibility of measuring the pH from the spectral characteristics of DOM fluorescence was also conducted. The synchronous fluorescence spectroscopy technique was used, in which both the excitation and observation wavelengths are scanned. A clear linear correlation was found between the ratio of the signals in two spectral bands and the pH. The application of this result with a lidar would imply the use of, at least, a dual wavelength excitation laser.

### Perspectives for 1991

The objectives for 1991 are as follows:

- to use the TRLF from an helicopter;
- to initiate the study of the weathering effects on oils and of the response of thin oil films;
- to further improve the analysis of the water column with the help of additional simulation experiments.

# 6.4 APPLICATION OF LASER SPECTROSCOPY TO THE CLASSIFICATION OF GREEN MATTER

***Summary of objectives***

- *To set up a database of laboratory and airborne time-resolved laser-induced chlorophyll-a fluorescence signatures of vegetation of known physiological state.*
- *To identify parameters, which are important for the design of an in-field ground based instrument.*

## 1990 Programme of Work

### Introduction

The 1990 programme for the EUREKA project LASFLEUR (EU 380) concentrated on:

- Research in the field of the laser-induced time-resolved chlorophyll fluorescence using the classical instrumentation of plant physiology and laser techniques, developed at IRSA.
- Development and testing of an image analysis system of fluorescence transients to monitor the photosynthetic activity of whole plants.
- Analysis of the UV induced blue fluorescence emission of vegetation.
- Preparation and execution of the first LASFLEUR-measuring campaign, including reflectance and microwave techniques.

The work undertaken in each of these is summarized below.

**1990 Milestones**

| | |
|---|---|
| January | Installation and testing of a laser-diode based photon counting system (IRSA/JRC and LURE/PARIS) |
| May | Beginning of laboratory measurements on controlled and stressed vegetation |
| September | Preparation of LASFLEUR campaign |
| October | First LASFLEUR measuring campaign |
| November | First remote chlorophyll fluorescence measurements |
| November | LASFLEUR workshop (LURE/Paris) |

### Signature Research of the Chlorophyll Fluorescence

Signature research of the chlorophyll fluoroscence has been undertaken in the laboratory and using remote techniques.

- Laboratory: The newly developed laser and physiological laboratories have been used to perform time-resolved fluorescence measurements on selected vegetation in well-known defined physiological states.
  First emphasis was given to measurements of the influence of the herbicide DCMU on the photosynthetic system. A decrease in the photosynthetic activity was directly related to the increase of the mean lifetime of the chlorophyll fluorescence.
  In addition the laboratories have been used for fluorescence signature measurements of vegetation at different chlorophyll fluorescence levels, with the objective being to investigate the behaviour of the chlorophyll fluorescence mean lifetime during fluorescence transient, known as the Kautsky-effect.
  A comparison has been made between time-decay measurements performed between the classical single photon counting technique and a laser/streak camera system, which is planned to be used in the remote detection of the fluorescence lifetime.
- Remote: First remote measurements (-100 m distance) have been performed using the laser/streak camera system.In principle it was possible to detect the fluorescence mean lifetime after an accumulation of the response of several thousand shots.The first remote measurements also demonstrated a strong influence of the depth of the illuminated target on the temporal aspect of the chlorophyll fluorescence.

### Fluorescence Image Analysis

For the characterization of the photosynthetic activity of a whole plant, a telecamera based image analysis system was developed and tested.

The first processed images of two types of plants have shown a non-uniform distribution of the photosynthetic activity within different leaves of the same and of different plants.

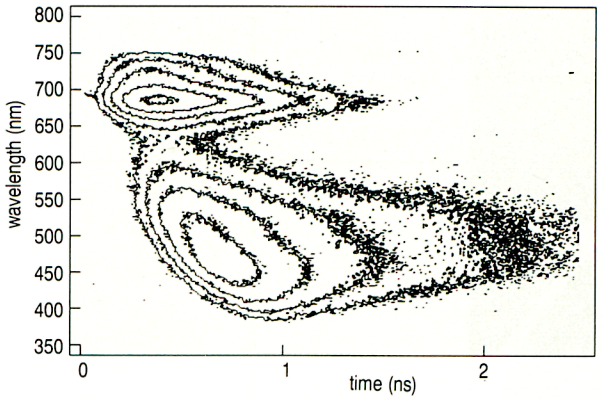


*Fig. 6.7: Remote spectro-temporal image of the induced fluorescence of a tobacco leaf. After UV excitation (g = 355 nm) a broad emission in the blue-green region (emission maxima around 480 nm and 520 nm) and the known chlorophyll fluorescence (emission maximum around 690 nm) appears.*

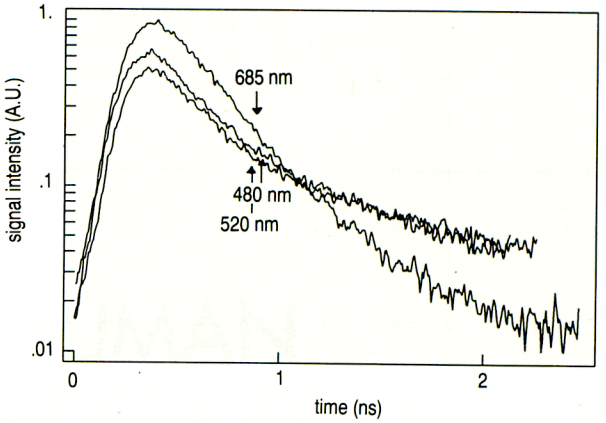


*Fig. 6.8: Fluorescence decay of the blue-green fluorescence at the maxima emission bands at 480 nm, 520 nm and of the chlorophyll fluorescence emission maximum at 690 nm.*

## Time-Resolved Blue Fluorescence (in Cooperation with LURE)

After UV-excitation a strong fluorescence emission in the blue-green region appears (maxima: ~ 480 nm and 530 nm).

For a better understanding of the origin of this emission, time and spectral resolved analyses have been performed. The overall emission was very sensitive to temperature changes and the water status of the vegetation.

## First LASFLEUR Campaign

The first LASFLEUR campaign, a joint experiment with LURE, DLR, and the Universities of Karlsruhe, Munich and Hannover, was held in 1990 in the laboratories of IRSA using several fluorescence techniques and advanced instrumentation of plant physiology. For a comparison reflectance and microwave signatures have been collected of the same targets. The main objective was to investigate the sensitivity of several fluorescence parameters to water stressed plants of wheat and maize.

After the data analysis, the final results were presented at the LASFLEUR workshop in Paris in November 1990.

## Perspectives for 1991

The objectives for 1991 are as follows:

- to investigate of the influence of temperature nutrient deficiency and air pollutants on the mean lifetime (laboratory);
- to study about the behaviour of the mean lifetime under natural illumination conditions (daily cycle);
- to undertake intensity analysis of the laser pulse used for excitation;
- to undertake remote measurements on targets with different geometry for the LASFLEUR modelling group of INRA.

# 7 HUMAN RESOURCES

## Institute Staff

| | |
|---|---|
| Scientific and Technical Staff | 66 |
| Administrative Support | 4 |
| Secretary Support | 9 |
| Total | 79 |

## Visiting Scientists and Scientific Fellows

| | |
|---|---|
| Visiting Scientists | 4 |
| Students | 11 |
| Total | 15 |

## Secondment from and to Other Laboratories

| | |
|---|---|
| Detached Experts | 2 |
| Total | 2 |

# 8 ANNEXES

# 8.1 IRSA PUBLICATIONS IN 1990

## Publications 1990

### JOURNAL PAPERS

#### Advanced Techniques

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# 8.3 GLOSSARY OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ATSR | Along Track Scanning Radiometer (a sensor on ERS-1) |
| AVHRR | Advanced Very High Resolution Radiometer |
| AVIRIS | Airborne Visible and Infra-Red Imaging Spectrometer |
| BNSC | British National Space Centre |
| CAP | Common Agricultural Policy |
| CASI | Compact Airborne Spectral Imager |
| CCT | Computer Compatible Tape |
| CEC | Commission of the European Communities |
| CI | Coordinating Investigator |
| CILSS | Comité Permanent Inter-Etats de la Lutte contre la Secheresse au Sahel |
| CORINE | COordination of INformation on the Environment |
| CZCS | Coastal Zone Colour Scanner |
| DCMU | (see Schmuck) |
| DG | Directorate General (of the European Community) |
| EARSEC | European Airborne Remote Sensing Capability |
| EDF | European Development Fund |
| EISAC | European Imaging Spectrometer Airborne Campaign |
| EPO | Earthnet Programme Office (of ESA) |
| ERDAS | Earth Resources Digital Analysis System |
| ERS-1 | European Remote Sensing satellite number 1 |
| ESA | European Space Agency |
| ESRIN | European Space Research Institute (of ESA) |
| EURACS | European Radar Cross Section data base |
| Eurostat | European Statistical Office |
| FAO | Food and Agriculture Organisation (of the United Nations) |
| FI | Fire Index |
| FLI | Fluoroscence Line Imager |
| FOV | Field Of View |
| GAC | Global Area Coverage (of AVHRR data) |
| GER | Geophysical Environmental Research Cooporation |
| GERIS | Geophysical Environmental Research Imaging Spectrometer |
| GIS | Geographical Information System |
| HIRIS | High Resolution Imaging Spectrometer |
| HRIS | High Resolution Imaging Spectrometer |
| HRPT | High Resolution Picture Transmission (AVHRR) |
| HVR | High Visible Resolution (sensor on SPOT) |
| ICSU | International Council of Scientific Unions |
| IFI | International Forest Investigation |
| IGBP | International Geosphere-Biosphere Programme |
| INRA | Institut National de la Recherche Agronomique |
| IRSA | Institute for Remote Sensing Applications |
| ISEI | Institute for System Engineering and Informatics |
| ISPM | Institut Scientifique des Pêches Maritines |
| ISY | International Space Year |
| JERS-1 | Japanese Earth Resources Satellite number 1 |
| JGOFS | Joint Global Ocean Flux Study |
| JPL | Jet Propulsion Laboratory |
| JRC | Joint Research Centre |
| LURE | Laboratoire pour Utilisation Rayonnement Electromagnetique |
| MAESTRO 1 | Multiple Airborne Experiments Towards Radar Observations - campaign number 1 |
| MERIS | Medium Resolution Imaging Spectrometer |
| MODIS | Moderate Resolution Imaging Spectrometer |
| MSS | Multi-Spectral Scanner (on the Landsat Satellite) |
| MVC | Maximum Value Composito (of AVHRR Data) |
| NASA | National Aeronautical and Space Administration (USA) |
| NDVI | Normalised Difference Vegetation Index |
| NERC | National Environment Research Council (UK) |
| NIR | Near Infrared part of the electro-magnetic spectrum |
| NOAA | National Oceanographic and Atmospheric Administration (USA) |
| OCEAN | Ocean Colour European Archive |
| PC | Personal Computer |
| PGO | Productivity of the Global Ocean |
| PI | Principle Investigator |
| SAFISY | Space Agency Forum of the International Space Year |
| SAR | Synthetic Aperture Radar |
| SIR-C | Shuttle Imaging Radar C |
| SNR | Signal to Noise Ratio |
| SPOT | Systeme Probatoire pour l'Observation de la Terre |
| SST | Sea Surface Temperature |
| SWIR | Short Wave Infrared part of the electro-magnetic spectrum |
| TM | Thematic Mapper (on the Landsat Satellite) |
| TREES | Tropical Ecosystem Environment Observations by Satellites |
| TRLF | Time Resolved Lidar Fluorosensor |
| UV | Ultra-Violet part of the electro-magnetic spectrum |
| VIS | Visible part of the electro-magnetic spectrum |
| WCRP | World Climate Research Programme |
| WMO | World Meteorological Organisation |
| WOCE | World Ocean Circulation Experiment |
| X-SAR | X-band SAR on SIR-C |

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This report presents the achievements of the Institute for Remote Sensing Applications (IRSA) of the Joint Research Centre (JRC) of the Commission of the European Communities (CEC) for 1990. The JRC is a European scientific and technical research centre established by the member states of the CEC. Its four sites in Belgium (Geel), Germany (Karlsruhe), the Netherlands (Petten) and Italy (Ispra) house 9 Institutes, each with its own focus of expertise.

IRSA, based at Ispra, was created in November 1988 as the result of a decision taken by the Council of Ministers regarding the restructuring of the Joint Research Centre. At this time the Institute was set a number of objectives:

- to evaluate and demonstrate possible applications of remote sensing in support of the sectorial policies of the Commission of the European Communities in areas such as:
  - Common Agricultural Policy (CAP) (agricultural statistics, land use),
  - Environmental Policy (land and sea protection),
  - Development (food resources and environmental protection in developing countries),
  - Fisheries (resources evaluation and conservation),
  - Regional Aid.
- to undertake research on advanced methods for the interpretation and utilisation of satellite data including their integration with geographical data.
- to help to stimulate the scientific community in the use of European satellites such as ERS-1, SPOT and the Polar Orbiting Platforms; this objective is complementary to that of the European Space Agency (ESA).

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